DOOSAN Infracore

65.99897-8080A

Operation & Maintenance Manual

MARINE DIESEL ENGINE

L136, L136T, L136TI, L086TI

MARINE GENERATOR ENGINE

AD136, AD136T, AD136TI, AD086TI

FOREWORD

This manual is designed to serve as an instruction for the Operation & Maintenance of marine propulsion engines (L136/T/TI/086TI) and marine auxiliary engines (AD136/T/TI/086TI), combined in one book.

The first half is explained for operation and the latter half is described for maintenance like disassembling, inspecting and re-assembling etc in order to help an understanding for the maintenance procedure more easily.

To keep the best performance and the durability of engine for a long time , CORRECT OPERATION and PROPER MAINTENANCE are essential.

In this manual, the following symbols are used to indicate the type of service operations to be performed.

Removal

Installation

Disassembly

Reassembly

Align the marks

Directional Indication

Inspection

Measurement

Adjustment

Cleaning

Pay close attention-Important

Tighten to specified torque

Use special tools of manufatur's

Lubricate with oil

Lubricate with grease

Some figures of this manual may be different from the actual appearance of the engine because of explaining them with the representative figure among these models.

If you have any question or recommendation in connection with this manual, please do not hesitate to contact our head office, dealers or authorized service shops near by your location for any services.

For the last, the content of this manual instruction may be changed without prior notice for some quality improvement. Thank you.

Sep. 2003

DOOSAN Infracore Co., Ltd.

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1. Specification

1.1. Engine Specification

1.1.1. L136/T/TI

Spec. \ Model		Units	L136	L136T	L136TL	L136TI
Engine type			4 cycle, in line, direct- injection, water cooled naturally aspirated	4 cycle, in line, direct- injection, water cooled with turbo charger		4 cycle, in line, direct- injection, water cooled with turbo charger & inter-cooler
Rating output (B.H.P)		PS(kW)/rpm	160(118)/2,200	200(147)/2,200	240(177)/2,500	230(169)/2,200
Displacement		cc	8,071			
Cyl. No. – bore(ø) x stroke		mm	6 - ø111 x 139			
Valve clearance at cold		mm	In. : 0.3 , Ex. : 0.3			
Low idling rpm		rpm	725 ± 25			
No load max. rpm		rpm	below 2,400		below 2,750	below 2,400
Mean effective press. (Initial)		kg/cm²	8.07	10.14	10.71	11.66
Mean piston speed		m/sec.	10.19		11.58	10.19
Compression ratio			17.6	16.7		
Max. firing pressure of cylinder		kg/cm²	80	117	128	106
Comp. pressure (at 200 rpm)		kg/cm²	28 (Initial condition)			
Governor type of injection pump			Mechanical all speed (R.S.V)			
Fuel consumption		g/PS.h	165	155	172	162
		liter/h	32	37	50	45
Injection timing (B.T.D.C)		deg.	18° ± 1°			14° ± 1°
Inj. nozzle opening pressure		kg/cm²	214 + 8			
Starting system			Electric Starting by starter motor			
Starter motor capacity		V- kW	24 V – 4.5			
Alternator capacity		V- A	24 V – 50			
Battery		V- Ah	24V – 150			
Cooling system			Indirect cooling by sea water with heat exchanger			
Cooling water capacity		lit	Max. : 27 , Min. : 25			
Fresh water pump type			Centrifugal type, driven by V- belt			
Sea water pump type			Rubber impeller type driven by gear			
Lub. Oil (Engine)	Pan capacity	lit	Max : 23, Min : 17 (Engine total : 25)			
	Pressure	kg/cm²	Full : 3.5, Idle: 1.2			
Direction of revolution	Crankshaft		Counter clockwise viewed from stern side			
	Propeller		Clockwise viewed from stern side			
Engine size (L x W x H)	Without M.G	mm	1,182 x 770 x 925	1182 x 766 x 925		1,182 x 825 x 925
	With M.G	mm	1,546 x 770 x 937	1,541 x 766 x 963		1,552 x 825 x 1,027
Engine dry weight	Without M.G	kg	735	745		773
	With M.G	kg	920	935		994

1.1.2. L086TI

Spec. \ Model		Units	L086TI		
			L086TIH	L086TIM	L086TIL
Engine type			4 cycle, in line, direct- injection, water cooled with wet-turbo charger & inter-cooler		
Rating output (B.H.P)		PS(kW)/rpm	285(210)/2,100	300(221)/2,300	360(265)/2,500
Displacement		cc	8,071		
Cylinder No. - bore(ø) x stroke		mm	6 - ø111 x 139		
Valve clearance at cold		mm	In. : 0.3, Ex. : 0.3		
Low idling rpm		rpm	750 ± 25		
No load max. rpm		rpm	below 2,310	below 2,530	below 2,750
Mean effective press. (Initial)		kg/cm²	15.14	14.55	16.06
Mean piston speed		m/sec.	9.73	10.66	11.58
Compression ratio			16.7		15.3
Max. firing pressure of cylinder		kg/cm²	130	130	135
Comp. pressure (at 200 rpm)		kg/cm²	above 28 (Initial condition)		
Governor type of injection pump			Mechanical all speed (R.S.V)		
Fuel consumption		g/PS.h	152	163	170
		liter/h	52	62	74
Injection timing (B.T.D.C)		deg.	15° ± 1°		
Inj. nozzle opening pressure		kg/cm²	214 + 8		
Starting system			Electric Starting by starter motor		
Starter motor capacity		V- kW	24 V - 4.5		
Alternator capacity		V- A	24 V - 50		
Battery		V- Ah	24V - 150		
Cooling system			Indirect sea water cooling with heat exchanger		
Cooling water capacity		lit	Max. : 25 , Min. : 23		
Fresh water pump type			Centrifugal type, driven by V- belt		
Sea water pump type			Rubber impeller type driven by gear		
Lub. Oil (Engine)	Pan capacity	lit	Max : 23, Min : 17 (Engine total : 25)		
	Pressure	kg/cm²	Full : 3.5, Idle: 1.2		
Direction of revolution	Crankshaft		Counter clockwise viewed from stern side		
	Propeller		Clockwise viewed from stern side		
Engine size (L x W x H)	Without M.G	mm	1,182 x 825 x 962		
	With M.G	mm	1,557 x 825 x 1,062		
Engine dry weight	Without M.G	kg	790		
	With M.G	kg	1,015		

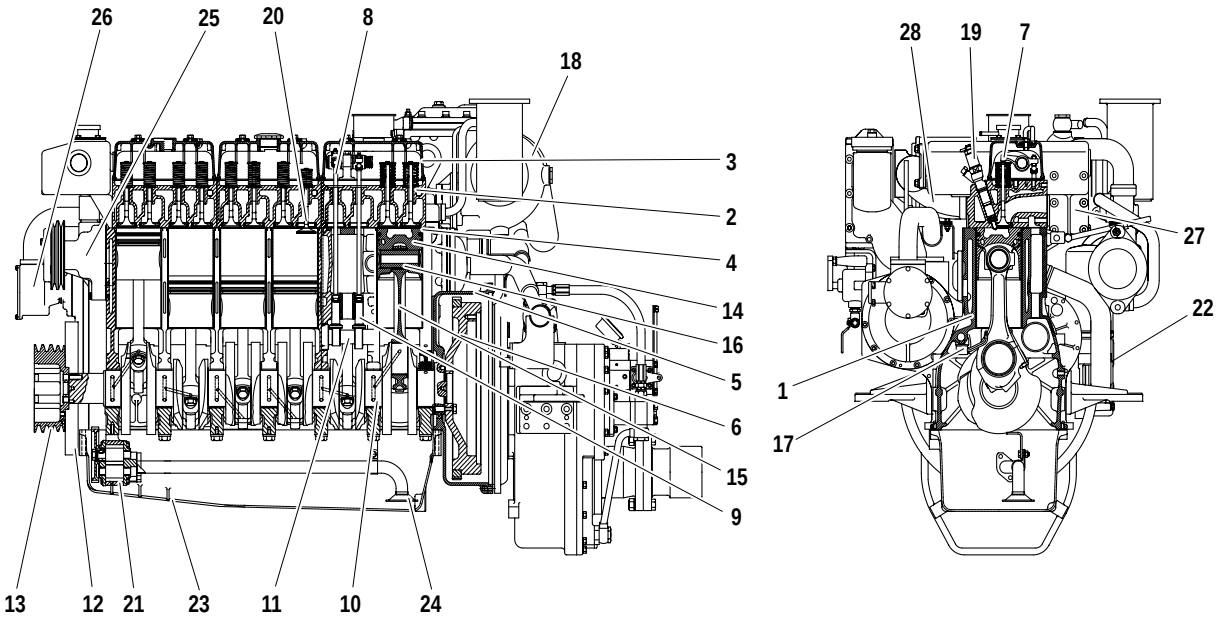
Note : *L086TIL model is not available right now but shows only the development target in future.*

1.1.3. AD136/T/TI/086TI

Spec. \ Model		Units	AD136	AD136T	AD136TI	AD086TI
Engine type			4 cycle, in line, direct- injection, water cooled naturally aspirated	4 cycle, in line, direct- injection, water cooled with turbo charger	4 cycle, in line, direct- injection, water cooled with turbo charger & inter-cooler	4 cycle, in line, direct- injection, water cooled with wet-turbo charger & inter-cooler
Rating output (B.H.P)	50 Hz	PS(kW) / rpm	105(77) / 1,500 (AD136F)	145(107) / 1,500 (AD136TF)	157(115) / 1,500 (AD136TIF)	205(151) / 1,500 (AD086TIF)
	60 Hz		126(93) / 1,800 (AD136S)	170(125) / 1,800 (AD136TS)	188(138) / 1,800 (AD136TIS)	253(186) / 1,800 (AD086TIS)
Displacement		cc	8,071			
Cylinder No. - bore(ø) x stroke		mm	6 - ø111 x 139			
Valve clearance at cold		mm	0.3 / 0.3			
Low idling rpm		rpm	725 ± 25			
No load max. rpm (50Hz / 60Hz)		rpm	Mechanical governor : 1575 (52.5 Hz) / 1890(63Hz),			
			Electric governor : 1575 (52.5 Hz) / 1890(63Hz),			
Mean effective press. (Initial)		kg/cm²	7.81 / 7.81	10.78 / 10.53	11.65 / 11.65	15.24 / 15.67
Mean piston speed		m/sec.	6.95 / 8.34			
Compression ratio			17.6	16.7		
Max. firing press. of cylinder		kg/cm²	74.4 / 79.5	105 / 117.3	109.1 / 127.5	109.1 / 127.5
Comp. Press. (at 200 rpm)		kg/cm²	About 28 (Initial condition)			
Governor type of inj. pump			Electric Governor			
Fuel consumption		g/PS.h	160 / 160	153 / 155	153 / 153	150 / 151
		liter/h	20 / 24	27 / 32	29 / 34	37 / 46
Injection timing (B.T.D.C)		deg.	18° ± 1°		14° ± 1°	15° ± 1°
Inj. nozzle opening press.		kg/cm²	224			
Starting system			Electric Starting by starter motor			
Starter motor capacity		V- kW	24 V - 4.5			
Alternator capacity		V- A	24 V - 50			
Battery		V- Ah	24V - 150			
Cooling system			Indirect cooling by sea water with heat exchanger			
Cooling water capacity		lit	Max. : 25, Min. : 23			
Fresh water pump type			Centrifugal type, driven by V- belt			
Sea water pump type			Rubber impeller type driven by gear			
Lub. Oil (Engine)	Pan capacity	lit	Max : 23, Min : 17 (Engine total : 25)			
	Pressure	kg/cm²	Full : 3.5, Idle: 1.2			
Revolution of Crankshaft			Counter clockwise viewed from stern side			
Engine only size (L x W x H)		mm	1,182x770x925	1,182x766x925	1,182x825x925	1,182x825x962
Engine only (Dry weight)		kg	735	745	773	790

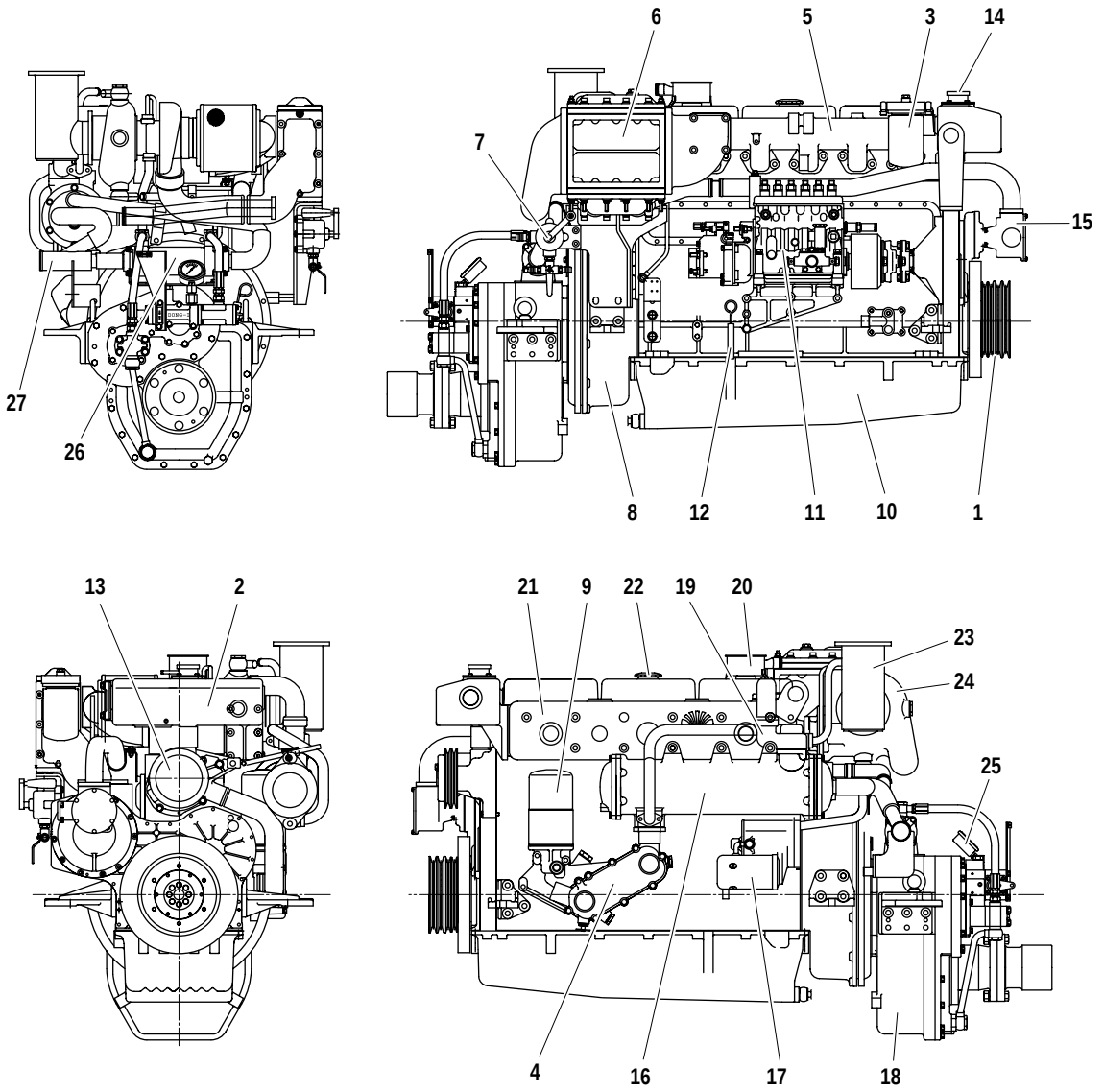
1.2. Engine Aspects

1.2.1. Engine Sectional Drawing



1. Cylinder block
2. Cylinder head
3. Cylinder head cover
4. Cylinder liner
5. Flywheel housing
6. Flywheel
7. Rocker arm
8. Push rod
9. Tappet
10. Crankshaft
11. Camshaft
12. Vibration damper
13. Camshaft pulley
14. Piston
15. Connecting rod
16. Piston pin
17. Piston cooling spray nozzle
18. Turbocharger
19. Multi-hole injection nozzle
20. Valve
21. Oil pump
22. Oil cooler
23. Oil pan
24. Oil suction pipe
25. Water pump
26. Sea water pump
27. Exhaust manifold
28. Intake manifold

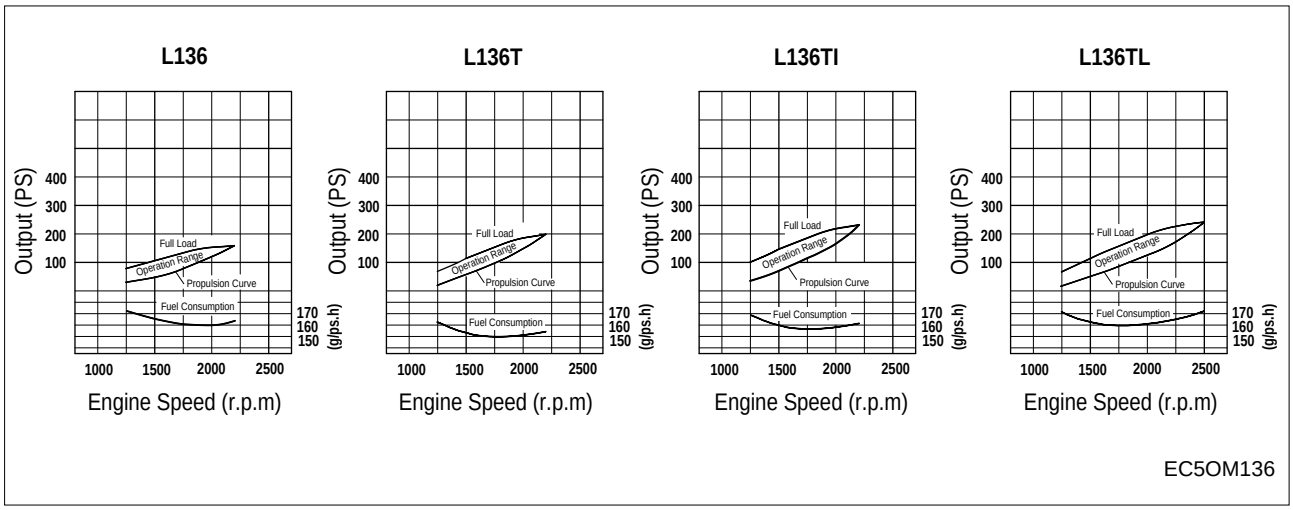
1.2.2. Engine Assembly



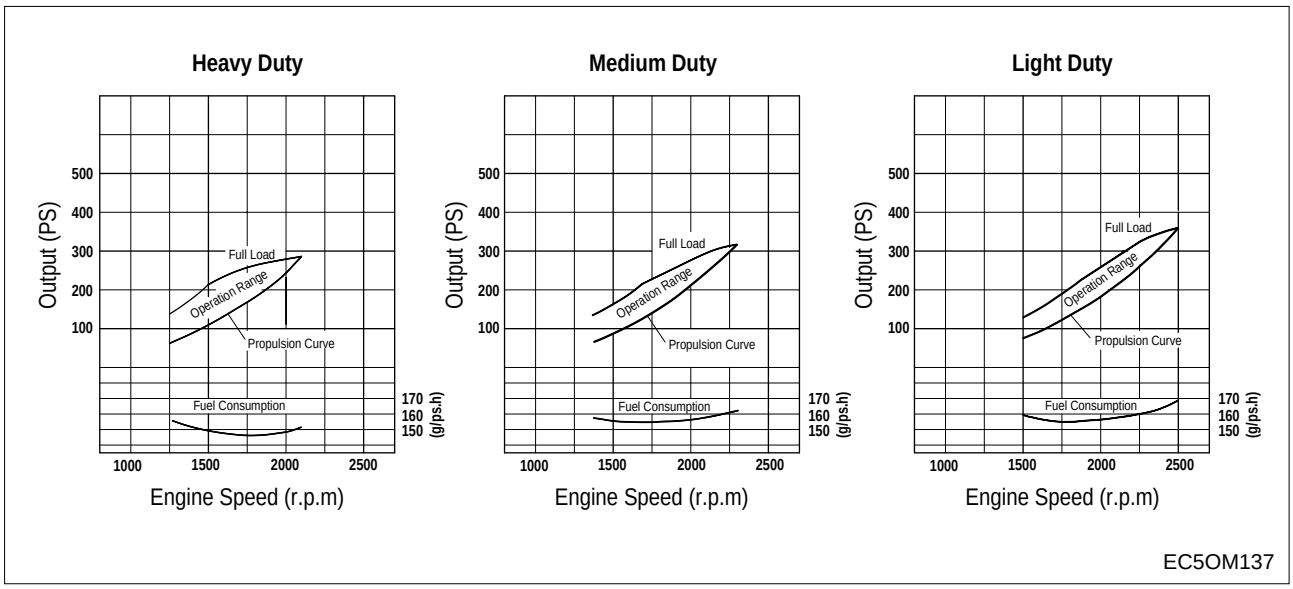
1. Crank pulley
2. Expansion tank
3. Fuel filter
4. Oil cooler cover
5. Intake manifold
6. Intercooler
7. Oil drain pump
8. Flywheel housing
9. Oil filter
10. Oil pan
11. Injection pump ass'y
12. Oil guide tube & level gauge
13. Water pump
14. Fresh water filler cap
15. Sea water pump
16. Heat exchange ass'y
17. Starter
18. Marine gear ass'y
19. Thermostat housing
20. Breather ass'y
21. Exhaust manifold
22. Oil filler cap
23. Exhaust outlet pipe
24. Turbocharger(wet)
25. Clutch oil press. gauge
26. Marine gear oil cooler
27. Sea water outlet pipe

1.3. Engine Performance Curve

1.3.1. L136 / L136T / L136TI /L136TL

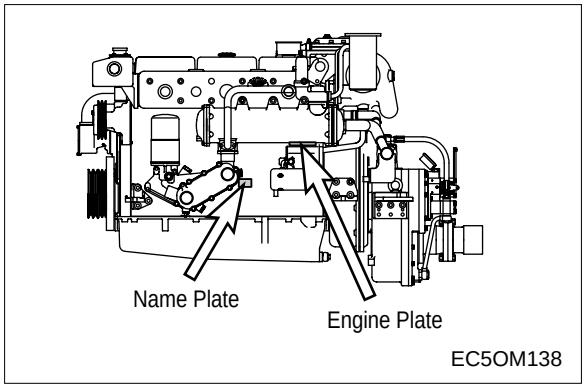


1.3.2. L086TI



1.4. Engine Model & Serial Number

The engine serial number is inscribed on the engine as illustrated. This number is required when requesting warranty and ordering parts. It is also referred to as engine model and serial number because of their location.



Note : *The engine model name (L136/T/TI/086TI) is described in the name plate on the cylinder block.*

- **Engine serial No. (Example : L086TI)**

EBPKM300001

- Serial No.
- Production Year(2003)
- Engine Model Suffix

2. Safety Regulations

2.1. General Notes

Day-to-day use of power engines and the service products necessary for running them presents no problems if the persons occupied with their operation, maintenance and care are given suitable training and think as they work.

This summary is a compilation of the most important regulations. These are broken down into main sections which contain the information necessary for preventing injury to persons, damage to property and pollution. In addition to these regulations those dictated by the type of engine and its site are to be observed also.

IMPORTANT : *If, despite all precautions, an accident occurs, in particular through contact with caustic acids, fuel penetrating the skin, scalding from oil, antifreeze being splashed in the eyes etc., consult a doctor immediately.*

2.2. Regulations Designed to Prevent Accidents with Injury to Persons

2.2.1. During commissioning, starting and operation

Before putting the engine into operation for the first time, read the operating instructions carefully and familiarize yourself with the “critical” points, If you are unsure, ask your DAEWOO representative.

- For reasons of safety we recommend you attach a notice to the door of the engine room prohibiting the access of unauthorized persons and that you draw the attention of the operating personal to the fact that they are responsible for the safety of persons who enter the engine room.
- The engine must be started and operated only by authorized personnel. Ensure that the engine cannot be started by unauthorized persons.
- When the engine is running, do not get too close to the rotating parts (All pulleys, Inj. Pump drive & propeller shafts, FPTO etc).
  Wear the close-fitting clothing as possible.

EC2OM009

- Do not touch the engine hot parts(Exh. Manifold & turbocharger connection pipes, Inter cooler & heat exchanger connection pipes..etc) with bare hands when it is warm from operation risk of burns.
- Exhaust gases are toxic. Comply with the installation instructions for the installation of DAEWOO marine diesel engines which are to be operated in enclosed spaces. Ensure that there is adequate ventilation and air extraction.

EC2OM010

- Keep vicinity of engine, ladders and stairways free of oil and grease. Accidents caused by slipping can have serious consequences.

2.2.2. During maintenance and care

- Always carry out maintenance work when the engine is switched off. If the engine has to be maintained while it is running, e.g. changing the elements of change-over filters, remember that there is a risk of scalding. Do not get too close to rotating parts.
- Change the oil when the engine is warm from operation.

CAUTION : *There is a risk of burns and scalding. Do not touch oil drain plug or oil filter with bare hands.*

- Take into account the amount of oil in the sump. Use a vessel of sufficient size to ensure that the oil will not overflow.
- Open the coolant circuit only when the engine has cooled down.

EC5OM135

CAUTION :
When remove the pressure of the filler cap while the engine is still hot, cover the cap with a cloth, then turn it left slowly to release internal steam pressure. This will prevent a person from scalding by hot steam spouted out.

- Neither tighten up nor open pipes and hoses (lube oil circuit, coolant circuit and any additional hydraulic oil circuit) during the operation. The fluid which flow out can cause injury.
- Fuel is inflammable. Do not smoke or use naked lights in its vicinity. The tank must be filled only when the engine is switched off.

- When using compressed air, e.g. for cleaning the heat exchanger, wear goggles.
- Keep service products (anti-freeze) only in containers which can not be confused with drinks containers.
- Comply with the manufacturer's instructions when handling batteries.

CAUTION :*Accumulator acid is toxic and caustic. Battery gases are explosive.*

2.2.3. When carrying out checking, setting and repair work

- Checking, setting and repair work must be carried out by authorized personnel only.
- Use only tools which are in satisfactory condition. Slip caused by the worn open-end wrenc could lead to Injury.
- When the engine is hanging on a crane, no one must be allowed to stand or pass under it.Keep lifting gear in good condition.
- When checking injectors, do not put your hands under the jet of fuel.
  Do not inhale at atomized fuel.
- When working on the electrical system disconnect the battery earth cable first.
  After repair engine parts, connect it up again last in prevent short circuits.

2.3. Regulations Designed to Prevent Damage to Engine and Premature Wear

(1) Never demand more of the engine than it was designed to yield for its intended purpose. Detailed information on this can be found in the sales literature. The injection pump must not be adjusted without prior written permission of DAEWOO.

(2) If faults occur, find the cause immediately and have it eliminate in order to prevent more serious of damage.

(3) Use only genuine DAEWOO spare parts. DAEWOO will accept no responsibility for damage resulting from the installation of other parts which are supposedly "just as good".

(4) In addition to the above, note the following points.

- Never let the engine run when dry, i.e. without lube oil, fuel or coolant. Use only DAEWOO-approved service products. (engine oil, anti-freeze and anticorrosion agent)
- Pay attention to cleanliness. The diesel fuel must be free of water. See "4.6. Fuel System".
- Have the engine maintained at the specified intervals.
- Do not switch off the engine immediately when it is warm, but let it run without load for about 5 minutes so that temperature equalization can take place.
- Never put cold coolant into an overheated engine.
- Do not add so much engine oil that the oil level rises above the max. marking on the dipstick.
  Do not exceed the maximum permissible tilt of the engine. Serious damage to the engine may result if these instructions are not adhered to.
- Always ensure that the testing and monitoring equipment (for battery charge, oil pressure, and coolant temperature) function satisfactorily.
- Do not let the sea water pump run dry. If there is a risk of frost, drain the water when the engine switched off.

2.4. Regulations Designed to Prevent Pollution

2.4.1. Engine oil, filter element, fuel filter

- Take old oil only to an oil collection point. Take strict precautions to ensure that oil does not get into the drains or into the ground and sea.
- The drinking water supply may be contaminated.
- Oil and fuel filter cartridges are classed as dangerous waste and must be treated as such.

2.4.2. Coolant

- Treat undiluted anti-corrosion agent and / or antifreeze as dangerous waste.
- When disposing of spent coolant comply with the regulations of the relevant local authorities.

2.5. Notes on Safety in Handling Used Engine Oil

Prolonged or repeated contact between the skin and any kind of engine oil decreases the skin. Drying, irritation or inflammation of the skin may therefore occur. Used engine oil also contains dangerous substances which have caused skin cancer in animal experiments. If the basic rules of hygiene and health and safety at work are observed, health risks are not to the expected as a result of handling used engine oil.

Health precautions

- Avoid prolonged or repeated skin contact with used engine oil.
- Protect your skin by means of suitable agents (creams etc.) or wear protective gloves.
- Clean skin which has been in contact with engine oil.
  - Wash thoroughly with soap and water. A nailbrush is an effective aid.
  - Certain products make it easier to clean your hands.
  - Do not use petrol, diesel fuel, gas oil, thinners or solvents as washing agents.
- After washing apply a fatty skin cream to the skin.
- Change oil-soaked clothing and shoes.
- Do not put oily rags into your pockets.

Ensure that used engine oil is disposed of properly.
- Engine oil can endanger the water supply -

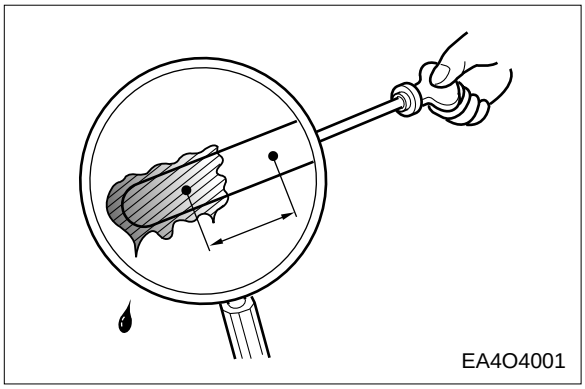
For this reason do not let engine oil get into the ground, waterways, the drains or the sewers. Violations are punishable. Collect and dispose of used engine oil carefully.
For information on collection points please contact the seller, the supplier or the local authorities.

3. Commissioning and Operation

3.1. Inspections Before Operation

3.1.1. Lubricating oil

- The notches in dipstick must indicate the oil level between max. and min. permissible.
- The measurement of the oil level must be done on a even water line and in 10 minutes after engine operating.
- Examining the viscosity and thecontamination of the oil smeared at the dipstick, replace the engine oil if necessary.



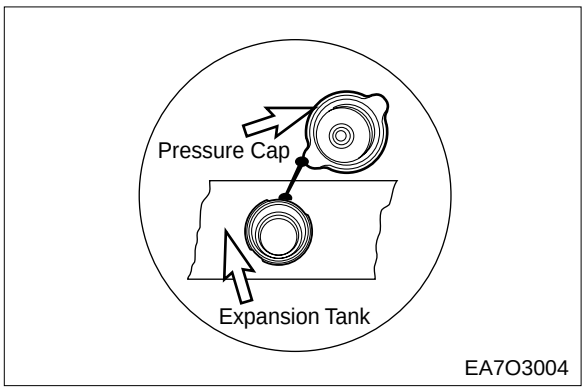
Caution : *If the installation angle of the engine exceeds 6 degrees, please remark the maximum and minimum level of the oil dipstick by engraving on the lube oil capacity of the engine. (Refer to 4.4. "Lubrication System")*

3.1.2. Cooling water

Checking the level of the cooling water in tank.

Check the opening pressure of the pressure valve using cap tester. Replace the filler cap assembly if the measured valve does not reach the specified limit.

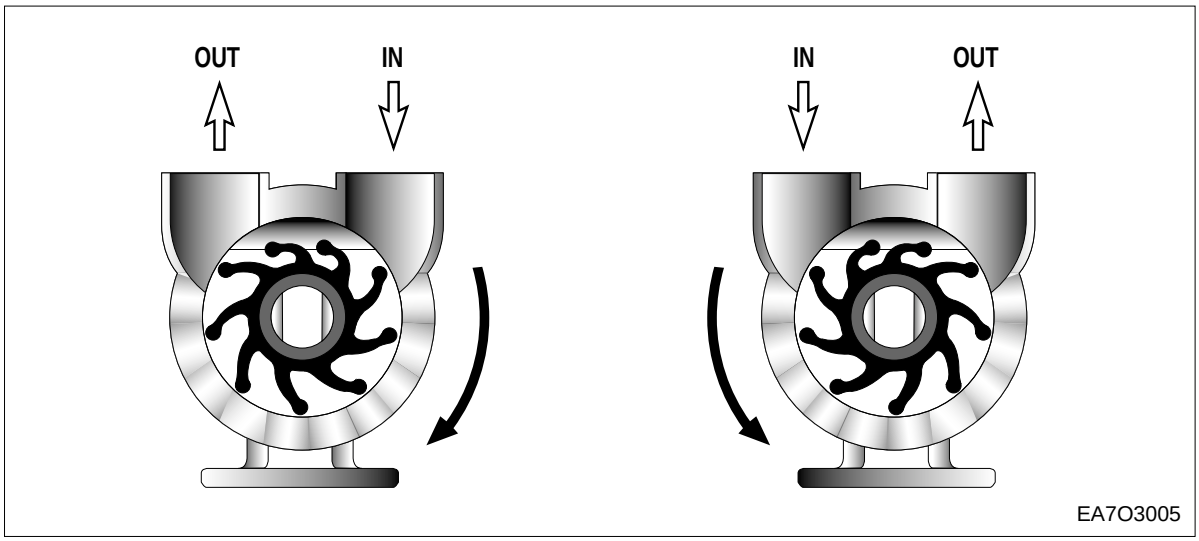
(Opening pressure of valve : 0.5 ~ 0.9 kg/cm^2)



NOTE : *Because it is dangerous to open the pressure cap quickly when coolant is hot, after covering the cap with a cloth and then lower the inside pressure of the tank by opening slowly at first, open it up.*

3.1.3. Sea water pump

The rotating direction of the pump impeller determines the location of the pump's intake and discharge ports.



- Over-tightened belt or gear load will reduce the bearing life of the sea water pump.
- Do not run sea water pump at dry for more than 20 seconds.
- Make sure that all valves / cocks in the sea water circuit are opened before run.
- If there is a risk of freezing weather, drain the water by loosening bolts of end cover.
- Temperature range : 5 °C (41 °F) ~ 60 °C (140 °F)

3.1.4. Intake and Exhaust Line

Check the condition of intake and exhaust piping lines, and air filter element. If piping lines or air filter is fouled or worn, clean or replace it.

3.1.5. Fuel Line

Check the leaking of fuel line by opening the fuel valve.

The contamination of fuel causes the clogging of the nozzle or the sticking of the components of injection pump. Therefore the cleanness of the fuel system should be maintained at any time.

3.1.6. Bottom of the Engine Room

The bottom of engine room would be as clean and dry as possible.

Check the bilge to prevent water accumulation.

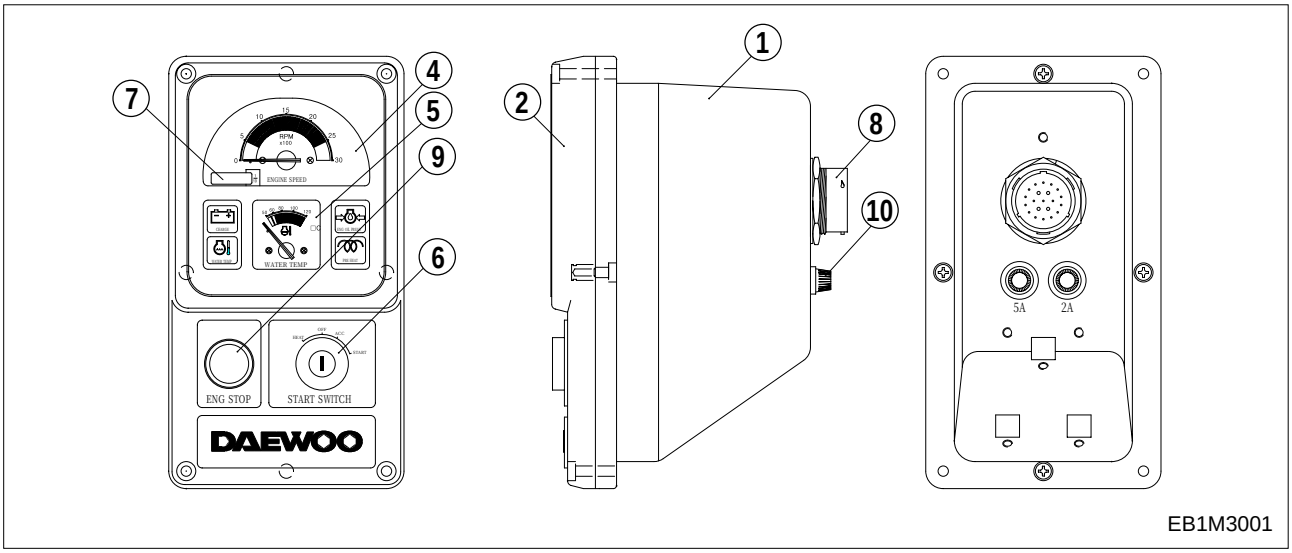
If water accumulation is unavoidable, do not allow the bilge water to reach the bottom of the engine. To install a bilge pump with an automatic control switch is a good solution.

Caution : *Excessive bilge water can cause engine damage like corrosion, rust and malfunction of engine parts.*

3.1.7. Gauge Panel

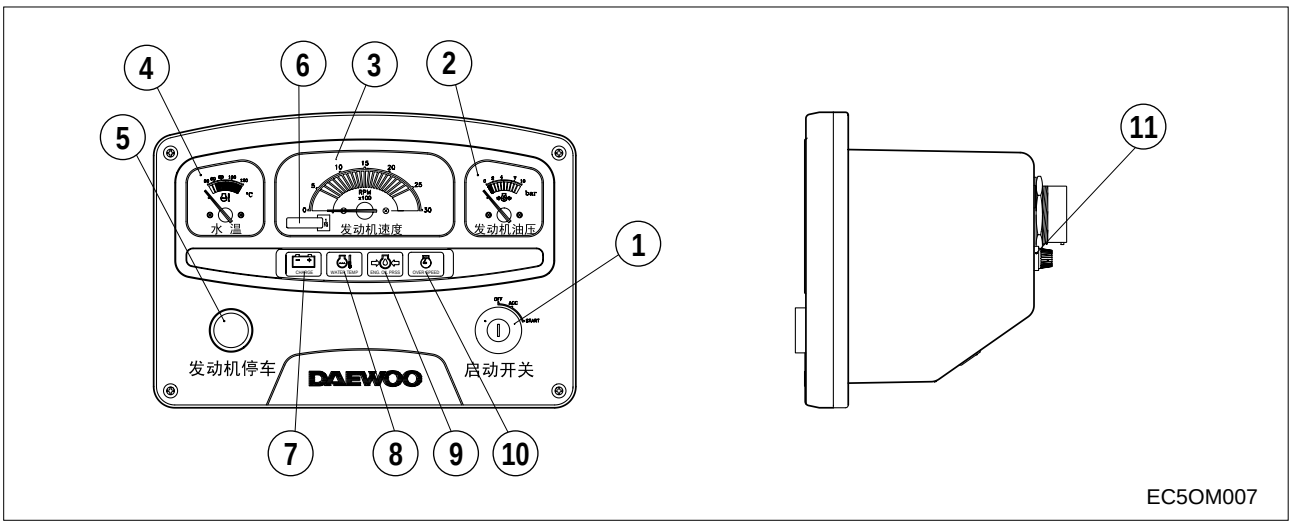
Check the all gauges of the panel whether the function is in normal or not.

● L136



① Case, Gauge
② Panel, Gauge
④ Meter, Tacho
⑤ Gauge, Water Temp
⑥ Key Switch Ass'y
⑦ Hour Meter
⑧ Connector
⑨ Button, Engine Stop
⑩ Fuse Holder

● L136T/TI/086TI



① Key Switch
② Engine Oil Pressure Gauge
③ Tacho-Meter
④ Water Temp. Gauge
⑤ Engine Stop Button
⑥ Hour Meter
⑦ Battery Warning Lamp
⑧ Water Temp. Warning Lamp
⑨ Oil Press. Warning Lamp
⑩ Over Speed Warning Lamp
⑪ Fuse

Before operating your engine, familiarize yourself with the instruments supplied with your boat.

3.1.8. Engine Stop & Warning Devices

L136/T/TI/086TI gauge panel is equipped with warning lamps and an audible alarm to alert the operator as follows.

1) Engine Stop Device (Stop solenoid)

Engine stop solenoid is operated with warning lamps and buzzer sound at the same time as follows.

- When the engine oil pressure is less than 0.5 kg/cm^2
- When the engine water temperature is more than 100 °C.(212 °F)

2) Engine Warning Lamps

Engine warning lamp is turned on with buzzer sound at the same time as follows.

- When the engine oil pressure is less than 0.5 kg/cm^2
- When the engine water temperature is more than 100 °C.
- When the battery is not charged.

The alarm horn will sound when the ignition is turned on and continue to sound until the key switch is shifted into “OFF” position or minimum oil pressure is obtained. This provides a functional test of warning system.

Should engine coolant overheat occurs, the alarm horn will sound and the engine is stopped by stop solenoid at the same time automatically. Proceed as follows:

- First, quickly observe the water temperature gauge for engine coolant overheat and / or needle oscillation indicating low coolant.
- If the temperature gauge indicates engine coolant overheat range, put the control lever back to the idle speed position IMMEDIATELY and shift the reduction gear control lever into the NETURAL position. Do not restart engine until the cause for the alarm has been found and corrected. Refer to **“Overheating”** in “8. Trouble Shooting” Chart.
- If the temperature gauge indicates high coolant temperature, check lack of coolant to fill expansion tank or thermal sensor malfunction.
- If the cause for the alarm cannot be found, contact your DAEWOO dealer.

3.2. Starting

3.2.1. Operation 1

After checking the warning lamps of the gauge panel and the NEUTRAL position of reduction gear control lever, turn the key switch to the START position to crank the engine, at once.
Behavior - When the key switch is placed in the START position.

3.2.2. Operation 2

After the engine is cranked, convert the key switch to the ACC position quickly.
Behavior - As the engine is cranked, don't fix the key switch too long (over 5 seconds) in the START position. If you do so, the starter may be malfunction.

If you fail the engine starting at first, restart the engine after waiting for 30 seconds at least to prevent the circuit malfunction of the starter.

3.3. Engine Break-in

All DAEWOO marine engines have been run for a short period of time as a final test at the factory. During the first 20 hours of operation, you must follow the ***Engine Break-In*** procedure to ensure maximum performance and long engine life.

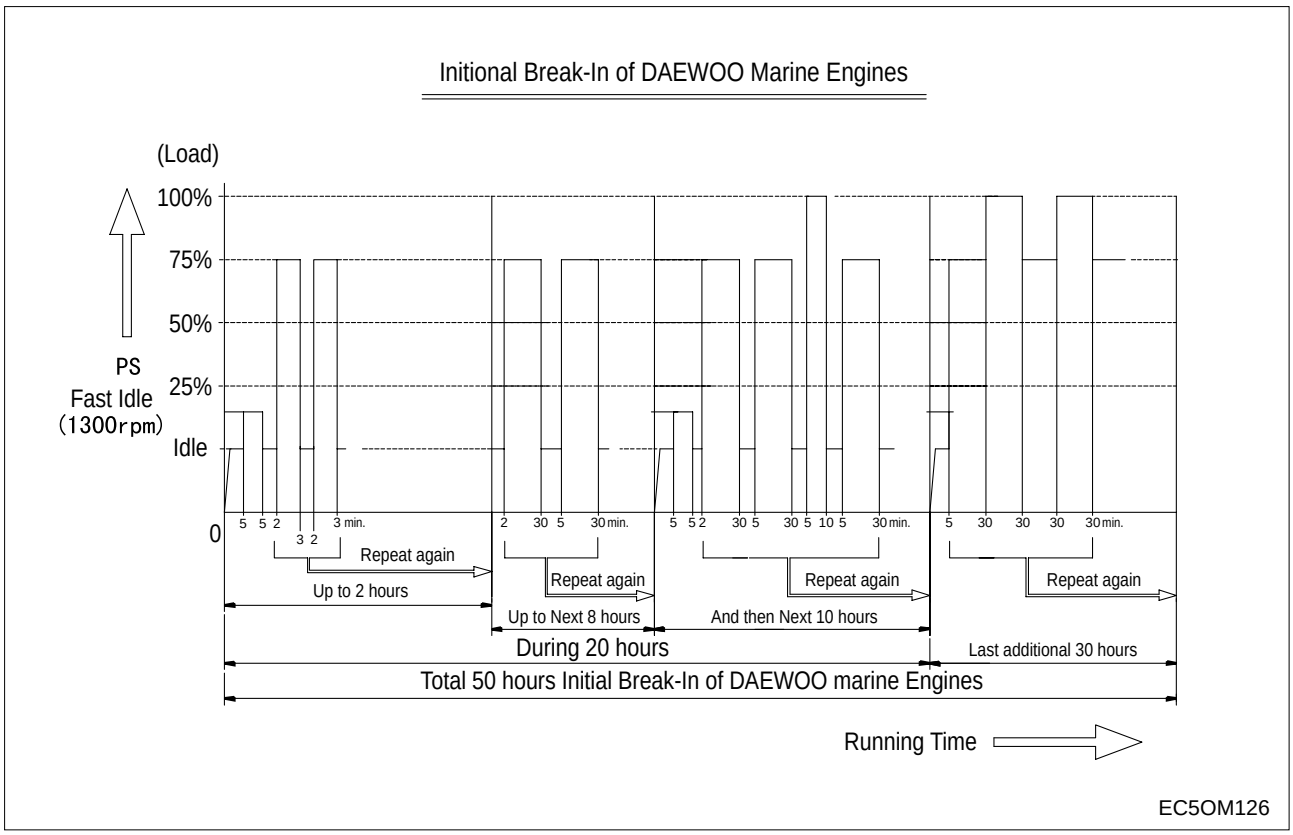
Note : *Failure to follow the **Engine Break-in** procedure may result in serious engine damage and will avoid the engine warranty.*

During the break-in period, be particularly observe as follows :

- Check engine oil level frequently. Maintain oil level in the safe range, between the "min." and "max." marks on dipstick.
- Watch the oil pressure warning lamp. If the lamp blinks whenever the boat attitude (i.e. turning, climbing on plane, etc.) is changed, it may be the oil pick-up screen not to be covered with oil. Check oil dipstick and if required, add oil to the oil pan. But do not fill over maximum level.

Note : *Oil pressure will rise as RPM increases, and fall as the engine RPM decreases. In addition, cold oil will generally show higher oil pressure for any specific RPM than hot oil. Both of these conditions reflect normal engine operation.*

- Watch the engine water temperature gauge and be sure there is proper water circulation. The water temperature gauge needle may fluctuate if water level in expansion tank is too low.



3.3.1. Initial two hours of break-in

For the first five to ten minutes of operation, operate engine at a fast idle (below 1,500 rpm). During the remaining first two hours of operation, accelerate to bring boat onto plane quickly and bring throttle back to maintain a planing attitude. During this period, vary the engine speed frequently by accelerating to approximately three-fourths throttle (1700 ~ 1800 rpm) for two to three minutes, then back to minimum planing speed (700 ~ 750 rpm).

After the engine has reached operating temperature, momentarily reduce engine speed, then increase engine speed, to assist the break-in of rings and bearings. Maintain planing boat attitude to avoid excessive engine load.

Note : *Do not run engine at any constant rpm for prolonged periods of time for this initial two hours of break-in.*

3.3.2. Next 8 Hours

During the next 8 hours, continue to operate at approximately three-fourths throttle or less (Minimum planning speed). Occasionally reduce throttle to idle speed for a cooling period. During this 8 hours of operation, it is permissible to operate at full throttle for periods of less than two minutes only 2 times.

Note : *Do not run engine at a constant rpm for prolonged periods of time during the break-in period.*

3.3.3. Final 10 hours

During the final 10 hours of break-in, it is permissible to operate at full throttle for five to ten minutes at a time. After warming engine to operating temperature, momentarily reduce then increase engine speed. Continue to operate at approximately three-fourths throttle. Occasionally reduce engine speed to idle to provide cooling periods.

Note : *Do not run engine at a constant rpm for prolonged periods of time during the break-in period.*

3.3.4. Operating after break-in 20 hours

When starting a cold engine, always allow the engine to warm up gradually. Never run the engine at full throttle until the engine is thoroughly warmed up.

And you'd better run the engine at three-fourths throttle (about 1800 ~ 1900 rpm) until additional 30 hours (after finishing break-in 20 hours) as possible.

Be sure to check the oil level frequently during initial 50 hours of operation since the oil consumption will be high until the piston rings are properly seated.

When the engine operation become to reach 50 hours in total including the break-in period 20 hours, replace the engine oil and oil filter to new ones. Refer to ***"4.4. Lubricating System".***

NOTE : *When engine is overheated, do not stop the engine immediately.*
Lower the engine load and run the engine to be a lower rpm as possible.

3.4. Inspection After Starting

During operation the oil pressure in the engine lubrication system must be monitored. If the monitoring devices register a drop in the lube oil pressure, switch off the engine immediately.And the charge warning lamp of the alternator should go out when the engine is running.

- Do not disconnect the battery or pole terminals or the cables.
- If, during operation, the battery charge lamp suddenly lights up, stop the engine immediately and remedy the fault in the electrical system.
- Engine should be stopped if the color, the noise or the odor of exhaust gas is not normal.
- Confirm the following things through warning lamps and gauge panel.

3.4.1. Pressure of lubricating oil

The normal pressure comes up to 1 kg/cm^2 (1.0 bar) at idling and 3 ~ 5 kg/cm^2 (3.0 ~ 4.9 bar) at rated speed. If the pressure fluctuates at idling or does not reach up to the expected level at high speed, shut down the engine immediately and check the oil level and the oil line leakage.

3.4.2. Temperature of cooling water

The cooling water temperature should be 71 ~ 85 °C in normal operating conditions. Abnormally high cooling water temperature could cause the overheating of engine and the sticking of cylinder components. And excessively low cooling water temperature increases the fuel consumption, accelerates the wears of cylinder liners and shortens the engine life-time.

3.5. Check After Initial 50 Hours Operation

To insure your continued boating enjoyment, you should check as follows:

- Change engine oil and oil filter cartridge.
- Change fuel filter cartridge.
- Check coolant level.
- Check the tension of all drive belts.
- Check engine mounting screws for tightness.
- Check for any deficiencies, malfunctions, signs of abuse, etc. Correction of any problems at this time will prevent the worsening of a minor problem and help ensure a trouble free boating season.

Note : *This time is a good opportune to discuss with your dealer about your engine etc which may have arisen after the first 50 hours of operation and establish a routine preventive maintenance schedule like "**4.2. Periodical Inspection & Maintenance".***

3.6. Operation in Winter Time

Pay special attention to the freezing of cooling water and the viscosity of lubricating oil.

3.6.1. Prevention against the freeze of cooling water

When not using anti-freeze, completely discharge the whole cooling water after engine running. The freeze of cooling water causes the fatal damages of the engine. Because the anti-freeze is used to prevent coolant from freeze and corrosion, it is always to be filled with the anti-freeze 35 ~ 40 % of the engine whole coolant.

3.6.2. Prevention against excessive cooling

Drop of thermal efficiency caused by excessive cooling increases fuel consumption. Therefore prevent the engine from excessive cooling. If the temperature of coolant does not reach to normal condition (71 ~ 85 °C) after continuous operation, examine the thermostat or the other cooling lines.

3.6.3. Lubricating oil

As cold weather leads to the rise of oil viscosity, engine speed becomes unstable after starting. Therefore the lubricating oil for winter (SAE 15W40 or 10W40) should be used to prevent this unstableness. Refer to ***"4.4. Lubricating System".***

3.7. Tuning the Engine

The purpose of an engine tune-up is to restore power and performance that's been lost through wear, corrosion or deterioration of one or more parts or components. In the normal operation of an engine, these changes can take place gradually at a number of points, so that it's seldom advisable to attempt an improvement in performance by correction of one or two items only.
Time will be saved and more lasting results will be obtained by following definition and thorough procedure of analysis and correction of all items affecting power and performance.
Economical, trouble-free operation can better be ensured if a complete tune-up is performed once every year, preferably in spring. Components that affect power and performance to be checked are:

- Components affecting fuel injection ;
  Nozzle, delivery valve, fuel filter, fuel water separator, etc.
- Components affecting intake & exhaust ;
  Air filter, inter-cooler, turbo-charger, silencer, good ventilation of engine room, etc.
- Components affecting lubrication & cooling ;
  Air & oil filter, anti- freeze, heat exchanger, rubber impeller, sea water filter, kingston valve, misalignment of propeller, stableness of bed frame, bent propeller blade, etc.

4. Maintenance and Care

4.1. General Instructions

1. Before performing service operation, disconnect the grounding cable from the battery for reducing the chance of cable damage and burning due to short-circuiting.
2. Use covers to prevent the disassembled parts and components from damage or pollution.
3. Engine oil and anti-freeze solution must be handled with care. They can cause damage for painted parts.
4. The use of proper tools or specified special tools is important to perform the efficient and reliable maintenance operation.
5. Use genuine DAEWOO parts necessarily.
6. Used cotter pins, gaskets, O-rings, oil seals, lock washer and self-lock nuts should be discarded. New ones should be used for re-assembled parts. If these are reused, normal performance can not be maintained.
7. To facilitate reassembling, keep disassembled parts neatly in groups. Fixing bolts and nuts for reassembled parts should be reused at the original position. They are varied in hardness or length because they are designed depending on their application.
8. Clean the disassembled parts prior to inspection or re-assembly. By using compressed air, make oil ports and etc. of them free from any foreign material.
9. Lubricate the surface of rotating and sliding parts with oil or grease before installation.
10. If necessary, use sealant onto gaskets to prevent leakage.
11. Carefully obey all specified torque to tighten bolts and nuts
12. When maintenance is completed, make a final check to be sure it has been done properly.

4.2. Periodical Inspection & Maintenance

In order to insure maximum, trouble-free engine performance at all times, regular inspection, adjustment and maintenance are vital before occurring any problems.

- Daily inspections in below figure should be checked every day.
- The following maintenance details should be executed thoroughly at regular internals.

Inspection		Daily	Every 50 hrs	Every 100 hrs	Every 250 hrs	Every 500 hrs	Every 600 hrs	Every 1,000 hrs
Cooling System	Coolant level check and refill	●						
	Contamination of the coolant check and the quantity of the anti-freeze						●	1 Year change
	Heat-exchanger and water cooling line cleaning (Change O-Ring & Gasket)							1,200hr
	V-belt check and adjustment	●						2,000hrs change
	Check thermostat and clean or exchange for excessive corrosion							1 years
	Impeller of sea water pump check	●						2,000hr change
Lubrication System	Oil level check	●						
	Lubrication oil exchange		● 1st		●			
	Oil filter cartridge replacement		● 1st		●			
	Marine gear oil exchange			● 1st			●	
Intake Exhaust Fuel System	Air filter element cleaning & change			● Clean			● Change	
	Inter-cooler cleaning							●
	Turbocharger cleaning							2,000hrs
	Exhaust gas check	●						
	Priming pump strainer cleaning				●			
	Fuel tank check & cleaning		●					
	Water separator cleaning			●				
	Fuel filter exchange		● 1st			●		
	Fuel Injection timing check							1 year
	Fuel Injection nozzle check							1 year
Electrical System	Warning lamps check	●						
	Battery charging check	●						
	Wiring harness check						●	
Cylinder	Cylinder compression pressure check							● needed
	In./ Ex. valve clearance adjustment							●

4.3. Cooling System

4.3.1. Coolant level check and refill

- Replenish the deficient coolant in the expansion tank every day before running. The coolant must be changed at intervals of 1,200 hours operation or six months whichever comes first. If the coolant is being fouled greatly, it will lead engine overheat or coolant blow off from the expansion tank.
- Clean fresh water should be used for engine coolant.
- Additional agent (35 ~ 40% anti-freeze and 3 ~ 5% anti-corrosion agent) should be mixed with fresh water for engine coolant to prevent the cooling system problem like freezing, corrosion and etc.

CAUTION : *Suitable mixture of anti-freeze and anti-corrosion agent can protect the engine corrosion from deteriorating and raises a boiling point, but by using unsuitable mixture engine components like water pump impeller and water jacket of cylinder block may be occurred a malfunction by any bad corrosion damage or cavitation.*

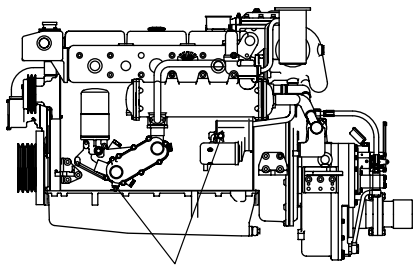
(1) Coolant replenishment

Let the plug in the highest level of the water lines or the upper plug of wet turbocharger open, and fill the coolant about three forth of the expansion tank slowly until the air bubbles in water do not come out through the plug hole. Then reassemble the plug.

After filling the coolant, run the engine at the idle rpm for around 5 minutes and you will find out the engine coolant level becomes lower than before cause of escaping the air bubbles in water. Then stop the engine and replenish additional coolant properly.

(2) Coolant change

- Open the pressure cap of expansion to remove the air pressure.
- Loosen two drain plugs. One is lower side of the oil cooler and another is upper side of the starter as figure.
- After drain reassemble the plug and replenish the coolant as same as “(1) Coolant replenishment”.



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CAUTION : *When remove the pressure of the filler cap while the engine is still hot, cover the cap with a cloth, then turn it left slowly to release internal steam pressure. This will prevent a person from scalding by hot steam spouted out from the filler cap.*

4.3.2. Contamination check of the coolant and the quantity of the anti-freeze

We recommend the engine coolant for DAEWOO marine engines should be mixture of fresh water and additional agent (35 ~ 40% anti-freeze and 3 ~ 5% anti-corrosion agent).
Check the quantity of the anti-freeze every 600 hours. From time to time, refill the anti-freeze as much as required.
You can check the quantity of anti-freeze and anti-corrosion agent by using a FLEETGUARD test kit simply as follow. (Fleetguard CC2602M : DHI No. ; 60.99901-0038)

1) Contamination check

● **How to use test kit (Striped pad)**

(1) Collect half of a coolant sample cup from a drain plug at the lower side of the oil cooler or cylinder block. Coolant must be between 10°C and 55°C when tested. Room temperature is preferred.

Do not collect the coolant from the expansion tank or overflow system.
The collected sample is less contaminated, so it can not be substituted for the quality of whole coolant.

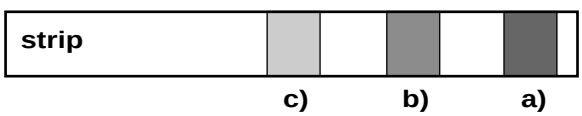
(2) Shake the bottle filled with sample coolant to mix well and take out one strip from bottle of the test kit. Then dip the strip in coolant sample for 3~5 seconds, take it out and shake it briskly to remove excess liquid.

Do not touch the pads on the end of the strip. Discard the kit if unused strips have turned brown for the nitrite test pad.

(3) Wait for 45 seconds after taking the strip out in the bottle of the sample coolant, then compare the color of the pads with the standard color chart of the test kit label and record the result as follows.

Caution : *All three pad readings must be completed **no later than 75 seconds** after dipping strip.*
Do not touch the stripe with fingers.

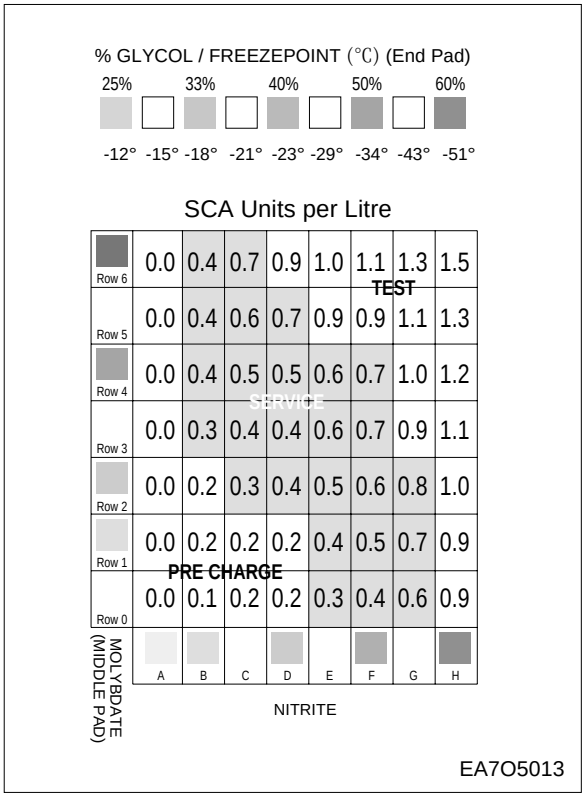
● **How to judge the strip**



a) Compare FREEZEPOINT (end pad) to chart and record result.
b) Next compare MOLYDATE (middle pad) to chart and record result.
c) Finally compare NITRITE test to chart and record result.

(1) Compare the end pad “a)” color of the strip with color blocks of a row at the upper part of the standard color chart (below of the letter “GLYCOL/FREEZE POINT”). Same color in the block of the row means the content of anti-freeze in the coolant. (Normal range is between 33% and 50%.)

(2) Compare the middle pad “b)” color of the strip with the color that the column block color of MOLYDATE at the left side of the table intersects the row block color of NITRITE at the bottom (pad “c)” color of the strip) on the table “SCA Units per Litre”. (Normal range of “SCA Units per Litre” is between 0.3 and 0.8 : “green color area”)



During the comparison, if uncertain about color match, pick the lower numbered block. (example: if the color of NITRITE pad is between standard color “D” and “F”, then use column E.)

(3) If the value of “SCA Units per Litre” is less than 0.3, refill the DCA4 liquid (anti-corrosion agent) a little, But larger than 0.8, Drain some amount of engine coolant and replenish the fresh water instead. The content of the anti-freeze and anti-corrosion agent can be regulated by this way.

Every year coolant must be replaced. It is essential the coolant should be mixture of fresh water, proper anti-freeze and anti-corrosion agent.

2) Quantity of anti-freeze

The anti-freeze, 35 ~ 40% of the whole coolant, is always to be used to prevent the cooling system from the corrosion. And in winter the amount of anti-freeze shown in the following table should be used in accordance with the ambient temperature.

As the individual freezing points corresponding to the proportions of antifreeze in the table are subject to change slightly according to the kind of antifreeze, you must follow the specifications provided by the antifreeze manufacturer.

Ambient Temperature (˚C)	Cooling water (%)	Anti-freeze (%)
Over -10	85	15
-10	80	20
-15	73	27
-20	67	33
-25	60	40
-30	56	44
-40	50	50

Any coolant loss due to engine operation must be replenished. But adding fresh water for coolant tends to lower the content of anti-freeze. Always replenish the coolant with a mixture of antifreeze and water, and keep the proper content of antifreeze (35 ~ 40%)

4.3.3. Heat exchanger and water cooling line cleaning

(1) Heat exchanger cleaning

If the heat exchanger tubes are clogged by small pieces or polluted by corrosion, the volume of supplied sea water will be reduced gradually. This would be cause of engine overheating.

- Disassemble both left and right side covers of the heat exchanger.
- Remove the clogged small pieces and clean the heat-exchanger tubes.

When the heat-exchanger tubes do cleaning, clean outside and inner side of tubes by using a small wire brush and pressurized water.

(2) Fresh water cooling line cleaning

If the cooling circuits are fouled with water scales or sludge particles, the cooling efficiency will be lowered.

The poor condition of the cooling system might be normally due to use of unsuitable anti-freezing agents so periodically clean the circuit interior with a cleaner.

Cooling system cleaning interval : Every 1,200 hours

4.3.4. V-belt check and adjustment

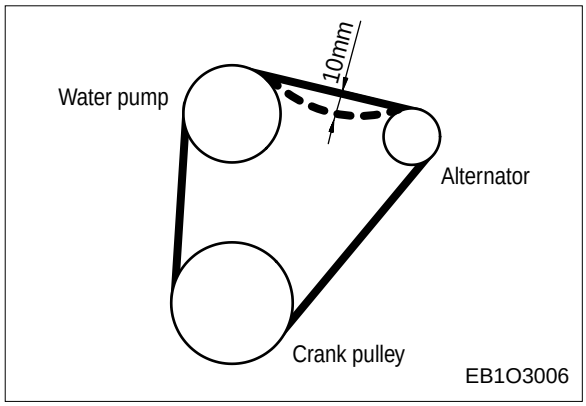
(1) Visual check

Check the belt for cracks, oil, overheating and wear.

(2) Tension check

By the finger-pressure, the belt is pressed by 10 ~ 15mm between the water pump pulley and the alternator pulley in normal condition.

For the adjustment of the tension, loosen the adjusting bolts which support the alternator, adjust the tension and tighten the bolts again.



(3) V-belt change

Change the belt if necessary after every 2,000 hours of operation.

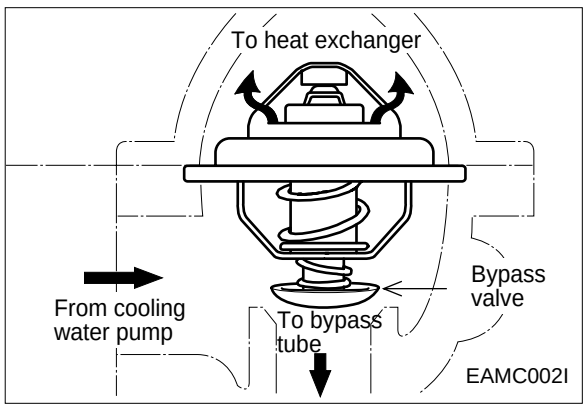
If, in the case of a multiple belt drive, wear or differing tensions are found, always replace the complete set of the belts.

Note : Always apply to DAEWOO genuine parts every replacement.

4.3.5. Thermostat check

The thermostat maintains a constant temperature of coolant (71 ~ 85 °C) and improves thermal efficiency of the engine by preventing heat loss.

Namely, when the temperature of coolant is lower than 85 °C, the thermostat valve is closed to make the coolant bypass to directly enter the water pump. When the coolant temperature rises to open wide the thermostat valve, the bypass circuit is closed and the water passage to the heat exchanger is opened so that the coolant is forced to flow into the heat exchanger.

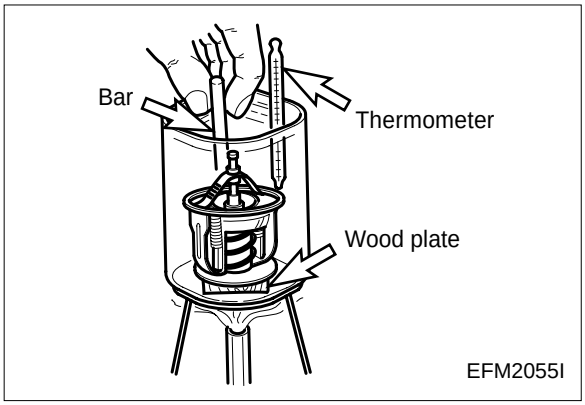


Item	Specifications
Type	Wax-pallet type
Open at	71 °C
Open wide at	85 °C
Valve lift	8 mm or more

● **Inspection**

(1) Check the wax pallet and spring for damage.

(2) Put the thermostat in a container of water, then heat the water slowly and check temperature with a thermometer. If the valve lift is 0.1 mm (starting to open) at temperature of 71 °C and 8 mm or more (opening wide) at temperature of 85 °C, the thermostat is normal.



● **Thermostat replacement**

(1) Precautions for handling

The wax pallet type thermostat does not react as quickly as bellows type one to a variation of temperature of coolant. Such relatively slow reaction is mainly due to the large heat capacity of the wax pellet type thermostat. Therefore, to avoid a sharp rise of coolant temperature, it is essential to idle the engine sufficiently before running it. In cold weather, do not run the engine at overload or overspeed it immediately after starting off.

(2) When draining out or replenishing coolant, do it slowly so that air is bled sufficiently from the entire cooling system.

(3) Replacing thermostat.

If the thermostat is detected defective, replace with a new one.

Check the thermostat and clean or exchange for excessive corrosion every 1 year.

4.3.6. Impeller of sea water pump check

The sea water pump is a rubber impeller type driven by gear. Every time the engine starts you should always check whether the kingston valve on the bottom of boat is opened or not.

If the engine is run in a dry impeller condition for more than 20 seconds, the rubber impeller is burned and cracked by high revolution of sea water pump.

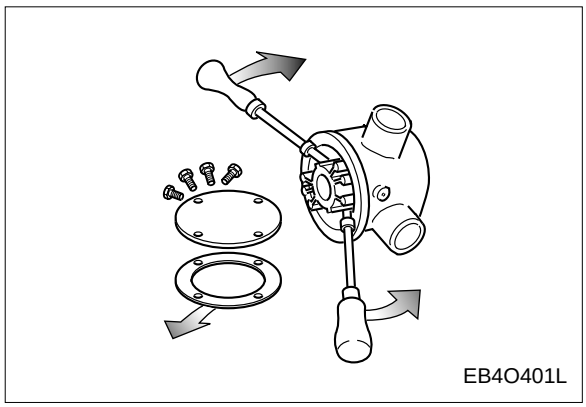
● **Impeller disassembly**

(1) Remove end cover screws, end cover and o-ring.

(2) Grasp the hub of impeller with water pump pliers and withdraw it by twisting to the rotating direction of the sea water pump body or remove it using two drivers like upper figure.

(3) Detach the cam unscrewed a bolt and clean the sealant of cam and body bore.

(4) Remove the wear-plate.



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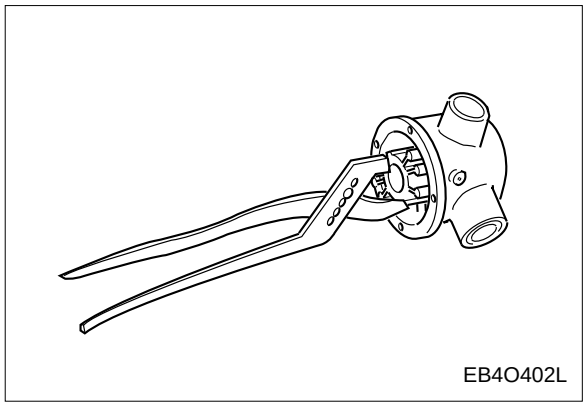

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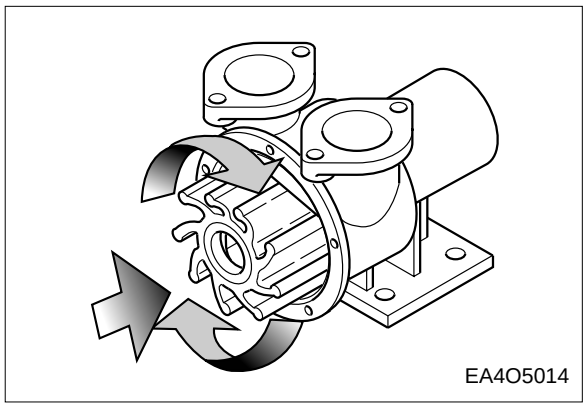
● Impeller assembly

(1) Install wear-plate in body bore, aligning slot in wear-plate with dowel pin in body.

(2) Apply a thin coat of sealant to cam screw threads and top side of cam and install in body with cam screw.

(3) Lubricate impeller bore and end surfaces of impeller with light coat of water pump grease and start the impeller in bore with a rotary motion until shaft key engage, then push it into the bore side by twisting into rotating direction.



EA4O5014

Caution : When you assemble the rubber impeller, do not use hammer to prevent the mechanical damage.

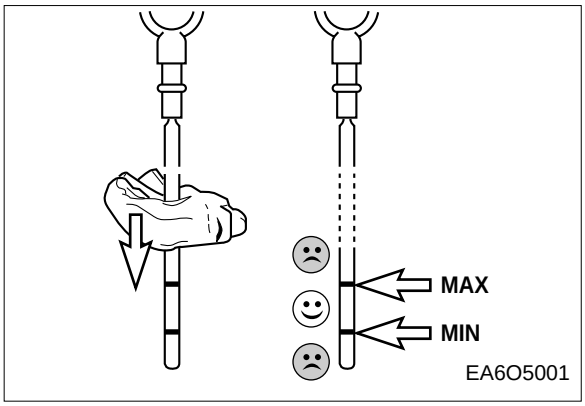
(4) Install O-ring and end cover and secure with end cover screws.

(5) After assembled the impeller open the kingston valve and check the leakage of sea water pump on running the engine.

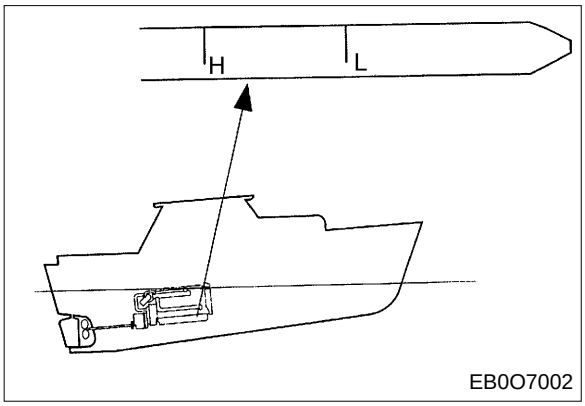
4.4. Lubrication System

4.4.1. Oil level check

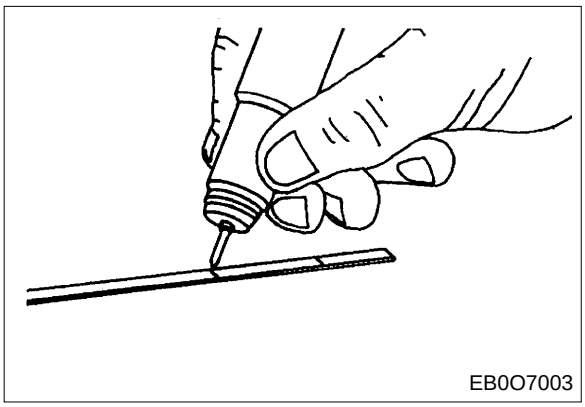
- The notches in dipstick must indicate the oil level between high and low permissible when the vessel is in the water and with its normal trim.
- The oil level should be checked with the engine horizontal and only after it has been shut down for about 10 minutes.
- Examining the viscosity and the contamination of the oil smeared at the dipstick, replace the engine oil if necessary.



CAUTION : *Do not add so much engine oil that the oil level rises above the maximum marking on the dipstick.*
Over filling causes excessive blow-by gas and will result in damage to the engine.



- **How to re-mark the oil dipstick**



Since the inclination angle of marine engine may vary greatly as vessels, the high and low oil levels on the dipstick should be also changed when the engine inclination angle is over 6 degree.

Dipstick should be re-marked by engraving on the lube oil capacity of each engine. Be sure to check and mark the oil levels between **High** and **Low** when the vessel is commissioning at first. Please note that stamping or notching will weaken the dipstick and the tip of the dipstick may break off in the oil pan.

The capacity of lube oil can be referred to **"1.1. Engine Specification"**.

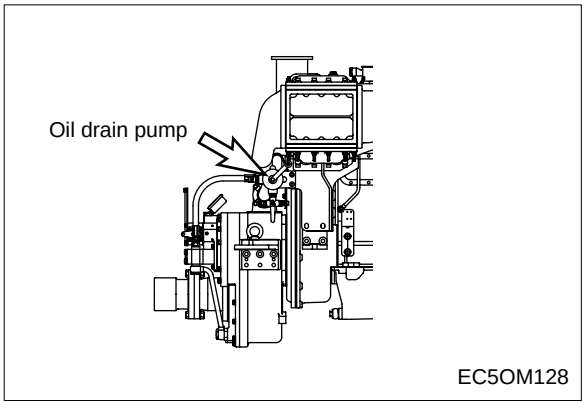
4.4.2. Lubrication oil exchange

Engine oil and the oil filter are important factors affecting engine life. They affect ease of starting, fuel economy, combustion chamber deposits and engine wear.

The first engine oil change should be after 50 hours of operation and next exchange will be performed every 250 hours. At the end of the break-in period (50 hours), change the engine oil and replace the oil filter cartridge to new one.

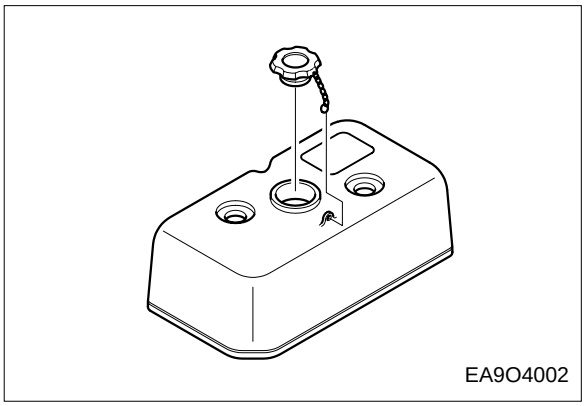
(1) Oil drainage

- While the oil is still hot, discharge the sump oil or marine gear sump oil by rotating oil drain pump manually.



- Refill new engine oil to the oil filler neck on the head cover in accordance with the oil capacity of the engine. Be careful about the mixing of dust or contaminator during the supplement of the engine oil.

  Then confirm that the oil level gauge indicates the vicinity of its maximum level.

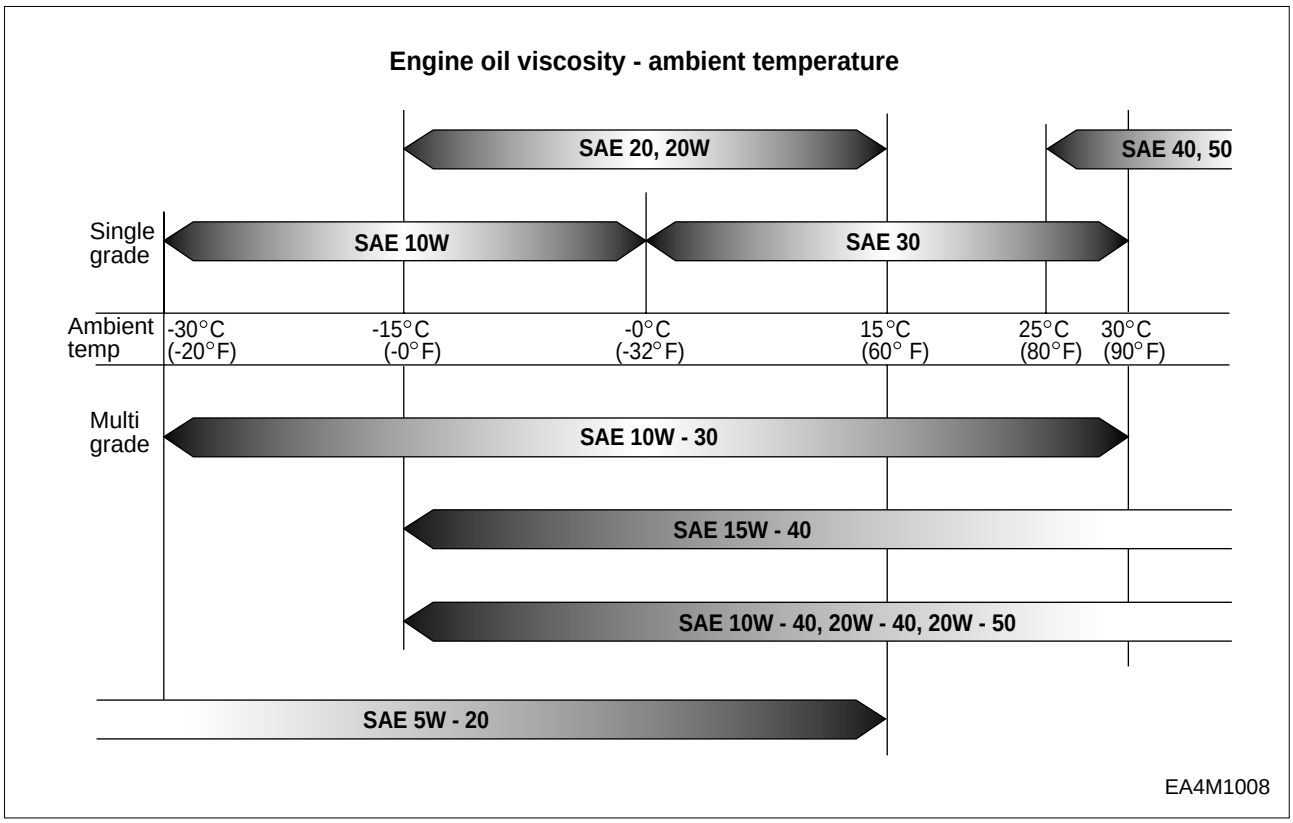


- For a few minutes, operate the engine at idling in order to circulate oil through lubrication system.
- Thereafter shut down the engine. After waiting for about 10 minutes, measure the quantity of oil and refill the additional oil if necessary.

- **Recommendation for lubrication oil**

  Initial factory filling is high quality break-in oil (API Service CH-4 grade). During the break-in period (50 hours), check the oil level frequently. Somewhat higher oil consumption is normal until piston rings are seated. The oil level should be maintained in the safe range between the Min. and Max. mark on the dipstick. To obtain the best engine performance and engine life, Engine oil is specified by API Service, letter designations and SAE viscosity numbers. If the specified engine oil is not available, use a reputable brand of engine oil labeled for API Service CH-4 and SAE viscosity 15W40 or 10W40.

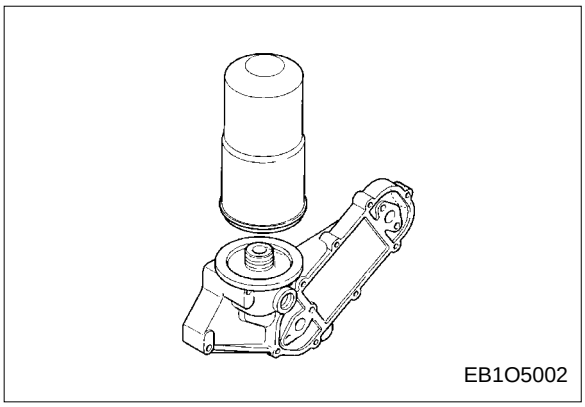
  Refer to oil identification symbol on the container.



4.4.3. Oil filter cartridge replacement

Every time oil exchanges, replace the oil filter cartridge.

- Drain engine oil by loosening the drain plug on the filter head.



CAUTION : *Don't forget tightening the drain plug after having drained engine oil*.

- Remove the oil filter by turning it counter-clockwise with a filter wrench.
- Wipe, clean the fitting face of the body contacting with the oil filter so that new oil filter cartridge can be seated properly.
- Lightly oil the O-ring and turn the oil filter until sealing face is fitted against the O-ring And then turn it in addition by 3/4 ~1 turns further with hand or the filter wrench.

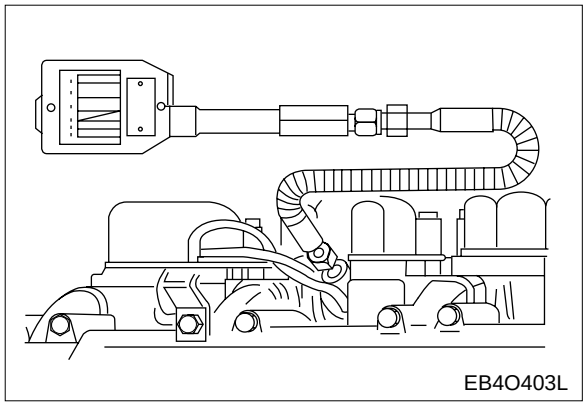
NOTE : *It is strongly advisable to use DAEWOO genuine oil filter cartridge for replacement.*

4.4.4. Marine gear oil change

Always apply to API Service SAE #30 for reduction gear oil Change the reduction gear oil at 100 hours of operation at first and next exchange will be performed every 600 hours.

4.4.5. Cylinder compression pressure check

- Stop the engine after warming up, and take out nozzle holder assembly.
- Install the special tool (compression gauge adapter) at the nozzle holder hole, and connect the compression pressure gauge there.



Standard value	24 ~ 28kg/cm^2
Limit value	24kg/cm^2 or less
Difference between each cylinder	Within ± 10 %

* Test Condition

Cooling water temperature 20°C, Engine rotation 200rpm (about 10 revolutions)

4.5. Intake & Exhaust System

4.5.1. Valve clearance adjustment

Usually should check the valve clearance of intake & exhaust every 1,000 hours after engine operation. Refer to **"6.3.24. Valve clearance adjustment"** details.

The valve clearances are to be adjusted at the times of the following situations.

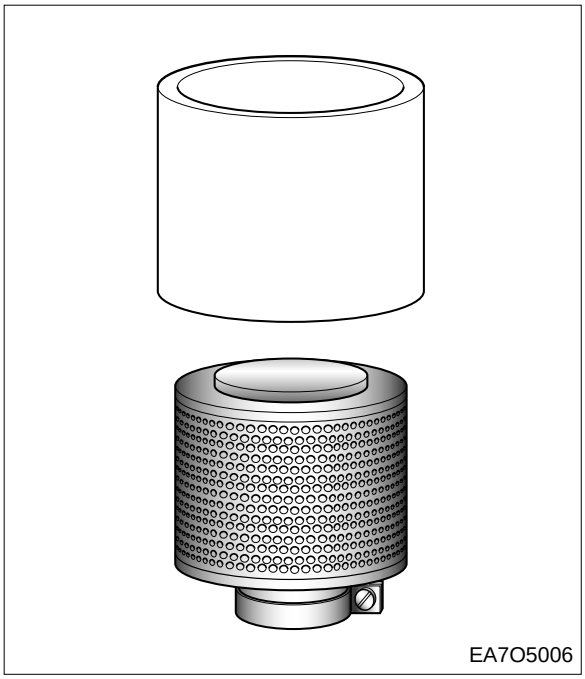
- After initial 50 hours operation.
- When the engine is overhauled and the cylinder heads are disassembled.
- When severe noise comes from valve train.
- When the engine is not normally operated, even though there is no trouble in the fuel system.

4.5.2. Air filter element cleaning & change

The engine life and performance depends on the intake air condition greatly.

A fouled air filter element results decreased intake air amount that leads decreased engine output and finally may cause an engine malfunction.

Further, a damaged air filer element results wear on the cylinder component or the valve mechanism etc. leading increased engine oil consumption and decreased engine output, finally leads to shorten the engine life.


EA7O5006

The air filter element should be cleaned periodically as follow.

- **Cleaning of the air filter element : Every 100 hours**
- **Exchange of the air filter element : Every 600 hours**

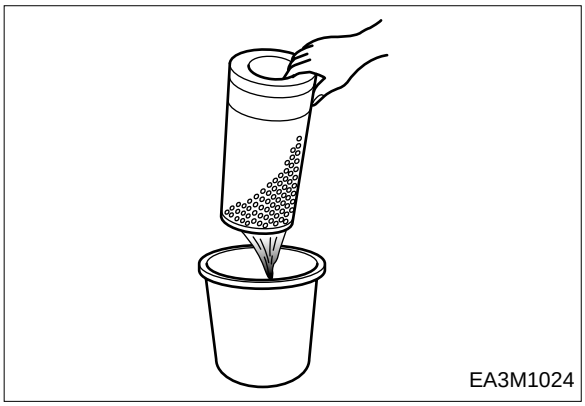
Replace the air cleaner if deformed, broken or cracked.

(1) Air filter element cleaning

- Wash the polluted element in warm water non-household detergent.
- Rinse the element with clean water
- Dry it thoroughly with natural air or electric fan.

  Don't use a flame or compressed air for dry.

  It makes damages to the element.


EA3M1024

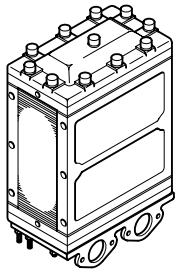
(2) Air filter element check

- Confirm inside of the element clean and dry.
- Replace the new element if tears, rips or damages are found.

4.5.3. Inter-cooler cleaning

Inter-cooler depends on the intake air conditiongreatly. The fouled air pollutes and clogs the air fins of the inter cooler. As a result of this, theengine output is decreased and the engine malfunction may be occurred. Therefore alwayscheck weather the intake air systems like air filter element are worn or polluted.

The inter-cooler has to be removed from theengine for cleaning.



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● **How to inter-cooler cleaning**

In order to maintain the heat transfer efficiency of the inter-cooler, it is necessary to clean it at regular intervals. For this purpose, dismantle the inter-cooler. In almost all cases, it will suffice to clean the individual parts in a hot alkaline solution, e.g. a 3 to 5% P3-FD solution. If hard and firmly adhering scale deposits continue to exist, a second treatment should be made with a descaling agent which will not corrode the cooler core. Use new gaskets when reassembling the inter-cooler.

Be sure to clean the sealing surfaces carefully before installing the gaskets.

Observe the specified pressure when making the hydraulic test.

Test gauge pressure	water side	400 kPa (4 bar)
	charge air side	300 kPa (3 bar)

Cleaning of inter cooler : Every 1,000 hours.

4.5.4. Turbocharger cleaning

- Turbocharger should be cleaned every 2,000 hours. The only points to be observed are the oil pipes which should be checked at every oil change for leakage and restrictions. Inspect the condition of turbocharger like oil leaks, and unusual turbo sounds periodically.
- Air cleaner element should be checked and cleaned periodically to prevent foreign matters from entering the inside of the engine.
- Should check and measure the pressure of intake air and exhaust gas periodically. If there is air leakage, should repair the problem at once not to occur the engine power loss and over heating.
- In case of operating in highly dust or oil-laden atmospheres, cleaning of the air compressorimpeller may be necessary from time to time. To this end, remove compressor casing **(Caution: Do not skew it!)** and clean in a non-acid solvent, if necessary use a plastic scraper.

  If the air compressor should be badly fouled, it is recommended that the wheel be allowed to soak in a vessel with solvent and to clean it then with a stiff non-steel brush. In doing so,

take care to see that only the compressor wheel is immersed and that the turbocharger is supported on the bearing casing and not on the wheel.

4.5.5. Exhaust gas check

Exhaust gas depends on much or less of it shows whether combustion condition of the engine is good or not. If exhaust gas is any abnormal condition like excessive smoke, white smoke, black smoke, the engine should be serviced maintenance from specialist.

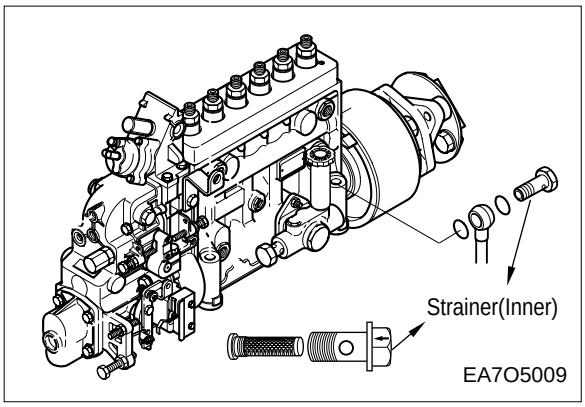
4.6. Fuel System

As fuel injection pumps and injection nozzles consist of very complicated and precise components, the contamination of fuel causes the clogging of the nozzle or the sticking of the injection pump components. Therefore, the cleanness of the fuel system should be maintained at any time.

If the engine is equipped with a fuel water separator, drain off any water that has accumulated. Water in fuel can seriously affect engine performance and may cause engine damage.

4.6.1. Priming pump strainer cleaning

Clean the priming pump strainer every 100 hours operation. The strainer is incorporated in the priming pump inlet side joint bolt. Clean the strainer with the compressed air and rinse it in the fuel oil.



4.6.2. Fuel tank check & cleaning

Fill the tank with recommended fuel and should reduce water condensation of the fuel tank as possible. Also it is important for the engine performance to keep the fuel cool.

Make sure fuel supply valves (if used) are opened before run.

In marine environment, the most likely fuel contaminants are water and microbial growth (black “slime”). Generally, this type of contamination is the result of poor fuel handling practices.

Black “slime” requires water in the fuel to form and grow, so the best prevention is to keep water condensation to a minimum in storage tanks.

If diesel fuel which contains moisture is used, injection system and cylinder liners, pistons will be damaged. Drain moisture and accumulated sediment from drainage device of storage tank regularly. You’d better change the element of the water separator or fuel filter cartridge several times until fuel of the suction line is cleaned.

NOTICE : *A galvanized steel tank should never be used for fuel storage, because fuel oil reacts chemically with the zinc coating to form powdery flakes which can quickly clog the fuel filters and damage the fuel pump and injection nozzles.*

● **How to select fuel oil**

Fuel quality is an important factor in obtaining satisfactory engine performance, long engine life, and acceptable exhaust emission levels. DAEWOO engines are designed to operate on most diesel fuels marketed today. In general, fuels meeting the properties of ASTM designation D975 (grades 1-D and 2-D) have provided satisfactory performance.

The ASTM 975 specification, however, does not in itself adequately define the fuel characteristics needed for assurance of fuel quality.

The properties listed in the fuel oil selection chart below have provided optimum engine performance. Grade 2-D fuel is normally available for marine service. Grade 1-D fuel should not be used in pleasure craft engines, except in an emergency.

<Fuel Oil Selection Chart>

General Fuel Classification	ASTM Test	No. 1 ASTM 1-D	No. 2 ASTM 2-D	DIN 51601
Gravity, °API #)	D 287	40 ~ 44	33 ~ 37	0.815 ~ 0.855
Flash Point Min. °F (°C)	D 93	100 (38)	125 (52)	131 (55)
Viscosity, Kinematic CST 100 °F (40 °C)	D 445	1.3 ~ 2.4	1.9 ~ 4.1	1.8 ~ 10
Cloud Point °F #)	D 2500	See Note 1)	See Note 1)	See Note 1)
Sulfur Content wt%, Max.	D 129	0.5	0.5	0.15
Carbon Residue on 10%, wt%, Max.	D 524	0.15	0.35	0.1
Accelerated Stability Total Insolubles mg/100 ml, Max. #)	D 2274	1.5	1.5	
Ash, wt%, Max.	D 482	0.01	0.01	
Cetane Number, Min. +)	D 613	45	45	> 45
Distillation Temperature, °F(°C)	D 86			
IMP, Typical #)		350(177)	375(191)	
10% Typical #)		385(196)	430(221)	
50% Typical #)		45(218)	510(256)	680(360)
90% +)		500 (260) Max.	625(329) Max.	
End Point #)		550(288) Max.`	675(357) Max.	
Water & Sediment %, Max.	D 1796	0.05	0.05	0.05

#) Not specified In ASTM D 975 +) Differs from ASTM D 975

Note : *The cloud point should be 6 °C (10 °F) below the lowest expected fuel temperature to prevent clogging of fuel filter by crystals.*

4.6.3. Water separator cleaning

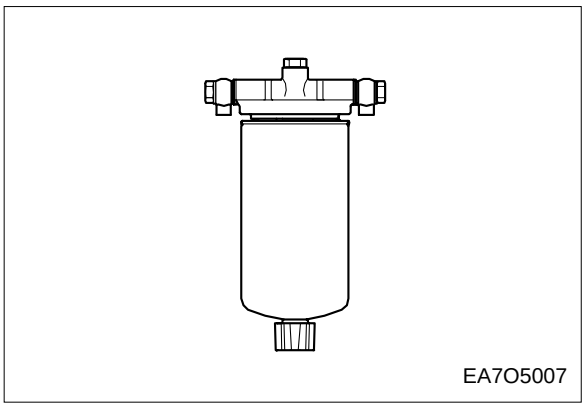
DAEWOO recommends the fuel water separator to install between fuel tank and fuel injection pump strongly.

Condensation formed in a partially filled tank promotes the growth of microbial organisms that can clog fuel filters and restrict fuel flow and cause the engine power decrease before.

Drain the accumulated moisture of the water separator every 100 hours to prevent engine damage.

4.6.4. Fuel filter exchange

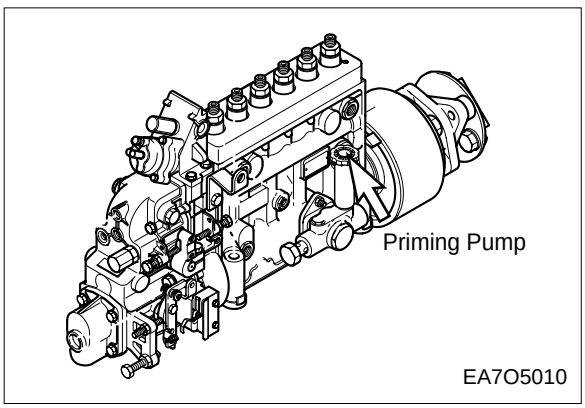
- Loosen the fuel filter by turning it counter-clockwise with the filter wrench. Discard the used filter a designated place.
- Wipe the filter fitting face clean.
- Supply fuel to the new filter and apply engine oil to the O-ring face lightly.
- Turn the new filter until the filter O-ring is fitted against the sealing face.
- And then turn the filter cartridge about 3/4 ~1 turn with hands.


EA7O5007

Fuel system bleeding

Whenever fuel filter is changed or the engine is stopped by cause of the fuel lack, the air of fuel line must be removed as follows.

Bleed the fuel by manually operating the priming pump with fuel filter outlet joint bolt and injection pump bleeder screw loosened.



EA7O5010

- Press the feed pump cap repetitively until the fuel without bubbles comes out from the bleeding plug screw.
- After the whole air is pulled out, close the plug screws of the filter and the pump.
- Confirm the resistance of fuel delivery by repetition pressing of the feed pump cap, Pressure and turn the priming pump cap simultaneously to close it.

4.6.5. Fuel injection timing check (by authorized specialist personnel)

Check the fuel injection timing every year. Refer to details in “6.3.27. Injection pump & timing “

Caution :
- Check the fuel injection pump housing for cracks or breaks, and replace if damaged.
- Check whether the lead seal for idling control and speed control levers have been removed or not.
- No alterations must be made to the injection pump. If the lead seal is damaged the warranty on the engine will become null and void.
- We strongly recommend that any faults developing in the injection pump should be taken care of by authorized specialist personnel.

4.6.6. Injection Nozzle check (by authorized specialist personnel)

Check the fuel injection nozzle every year or increasing the smoke excessively.
Refer to details in “7.3.3. Fuel injection nozzle”.

4.7. Electric System

4.7.1. Warning lamps check

Check the lamps of the gauge panel carefully whether the lamp is switch on or not while the engine is running. The oil warning lamp should be switched on below 0.5 bar of the oil pressure and the water temp warning lamp should be switched off under 95 °C of water temperature (normal condition).

4.7.2. Battery charge check

Always check whether the battery capacity is sufficient or not before sailing far away from harbor.

4.7.3. Wiring harness check

Check the engine wiring is loosened, shorted or worn every 600 hours.

4.8. Cylinder

4.8.1. Valve clearance adjustment

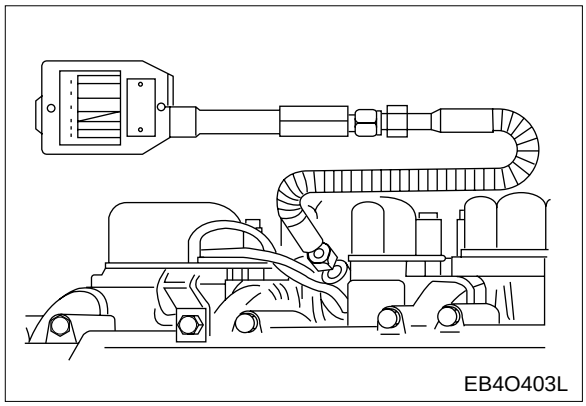
Usually should check the valve clearance of intake & exhaust every 1,000 hours after engine operation. **Refer to "6.3.26. Valve clearance adjustment"** details.

The valve clearances should be adjusted at the times of the following situations.

- After initial 50 hours operation.
- When the engine is overhauled and the cylinder heads are disassembled.
- When severe noise comes from valve train.
  - When the engine is not normally operated, even though there is no trouble in the fuel system.

4.8.2. Cylinder compression pressure check

- Stop the engine after warming up, and take out nozzle holder assembly.
- Install the special tool (compression gauge adapter) at the nozzle holder hole, and connect the compression pressure gauge there.


EB4O403L

Standard value	24 ~ 28kg/cm^2
Limit value	24kg/cm^2 or less
Difference between each cylinder	Within ± 10 %

* Test Condition

Cooling water temperature 20°C, Engine rotation 200rpm (about 10 revolutions)

4.9. Engine Preservation Points for a Long Time

Preserved engine for a long time should be prevented from corrosion or entering faulty matters. Especially the external and internal major components of the engine are likely to corrode. Please take care of the engine to maintain its good performance as follows.

- Drain the engine coolant completely and fill flesh water into the engine. Then run it sufficiently until washing out the engine coolant line.
  Finally drain the water, and refill new coolant (flesh water with 35 ~ 40% anti-freeze).
- Run the engine until the temperature of engine coolant is reached to normal condition (71 ~ 85 °C), after then stop the engine.
- Drain engine oil by removing the drain plug of the oil pan or using the oil drain pump. Then refill new engine oil up to “MAX” mark line and change oil filter cartridge to new one.
  Prior to changing the oil, run the engine for 10 minutes. Drain engine oil while the engine is still hot. It is helpful to drain the faulty matters attached in the bottom of the oil pan.
- Close the valve or the cock of the fuel tank securely. Then detach the fuel filter and the water separator to clean them or replace with a new one.
- Run the engine about 5 minutes in order to circulate the new fuel through the all fuel lines completely.
- Disassemble the air filter to clean. If the element is fouled or worn severely, replace it with a new one.
- Drain the reduction gear oil completely, then clean the strainer that is assembled in the reduction gear.
  Refill the specified oil (SAE #30, above API CC grade) up to the “MAX” level.
- While the engine is running at idle rpm for 5 minutes, shift the control lever position of the reduction gear in turn (eg. “Neutral” - “Forward”- “Neutral” - “Reverse”) to circulate the oil completely.
- Put the engine throttle lever at the idle position then reduction gear and FPTO lever at “switch off” position (Neutral & OFF).
- Drain the engine coolant completely and let the drain plugs removed.
- Close the kingston valve of the sea water line tightly. To avoid damage cause of freezing, drain the water of the heat exchanger, inter cooler, reduction gear oil cooler completely and keep the plugs opened.
  Finally don’t forget to detach the sea water pump impeller and preserve it at a dark place.
- First of all, disconnect the battery wire (negative pole), then detach the other cables.
  Clean battery and all cables. After that replenish the distilled water for battery. (for refill type)
  DAEWOO battery is maintenance free type, so there is no need to refill the water.
  To protect corrosion, apply the grease on the wire terminals of the battery.
- Loosen the V-belt(s) to release the pulley bearing from loaded tension and insert some pieces of paper between V-belt(s) and the pulley grooves.
- At least run the engine at idle rpm or a little more for 10 minutes once 10 days in order to lubricate all lubrication system and charge the batteries of the engine.
- The engine not used for a long time should be checked the condition regularly.
  Apply the grease on the engine parts to keep from rust.

4.10. Management for Sunken Engine

If the engine is sunk in sea water, remove the moisture of all engine parts as soon as possible and ask after service of your DAEWOO dealer at once.

All parts of the engine should be disassembled to remove the salty moisture. After this, engine oil should be applied onto the parts at once. Finally check whether the components of the engine are dried, eroded away or damaged especially components of the fuel system. These actions must be finished quickly without delay. If not, engine fatal damage may result from salty corrosion.

Be sure to install the auto bilge pump in the bottom of the engine room. It can be a good solution to keep the water level below flywheel housing and to prevent overflowing with water.

5. Main Accessory Parts

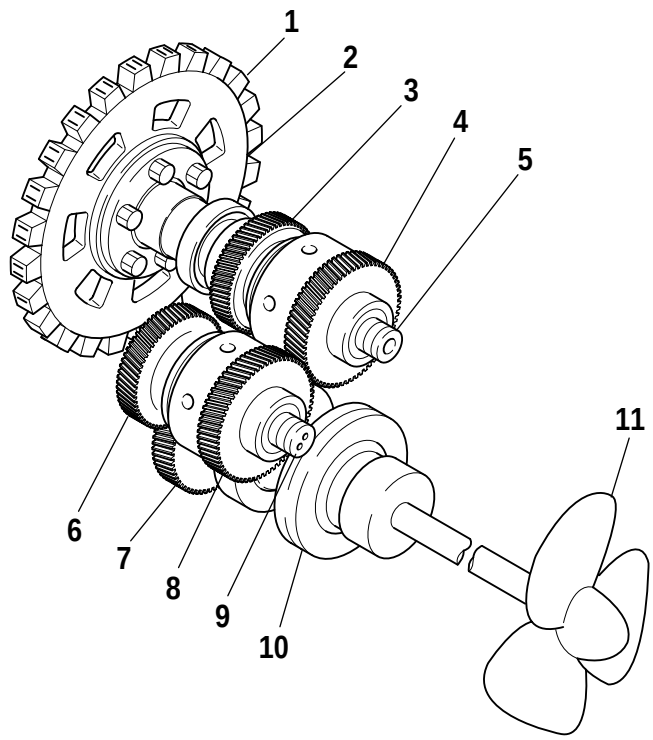
5.1. Reduction Gear

Refer to “reduction gear manual” provided with engine separately for detail operation and maintenance of reduction gear.

5.1.1. Construction and operation

The reduction gear is used for high-speed engine and consists of 4 major components such as input shaft, gear shaft, output shaft, and housing.

The clutch for forward and reverse movements is composed of a hydraulic wet-type and multi-plate type. The construction and power line is as follows;



EFM6006I

<Power line>

Neutral : 1-2-5-4-8

Forward : 1-2-5-3-7-10

Reverse : 1-2-5-4-8-9-6-7-10

1. Rubber block
2. Spider
3. Forward pinion
4. Reverse drive gear
5. Input shaft
6. Reverse pinion
7. Output shaft
8. Reverse drive gear
9. Gear shaft
10. Propeller shaft

5.1.2. Characteristics

The hydraulic-type clutch is composed of forward main body, reverse main body, output shaft, and selector valve..

The selector valve assembly installed on the external part is a device designed to control forward, neutral, and reverse movements and also it can be remote-controlled. The oil pumped up at the pump supplies hydraulic pressure for the clutch assembly, lubricating portions on gear and bearings, and cooling system. But when assembling this hydraulic type clutch, use care so that it is aligned with the engine correctly.

5.1.3. Operation

(1) Before operation

- Check the tightening bolts and nuts on the components as a whole for looseness.
- Check the oil level with the oil level gauge.
  (Run the engine at idle for a few minutes, then stop it before checking the oil level.)
- Place the control lever in the neutral position before starting the engine.

(2) Starting

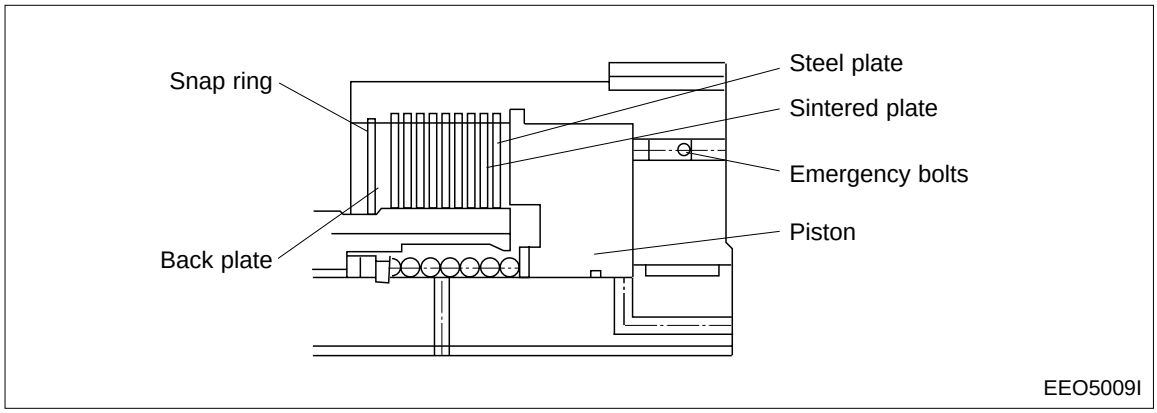
- Run the engine at idle for about 10 minutes.
- Check for oil leaks, unusual sound, temperature, etc. during the engine idling.
- While checking the clutch pressure, increase the engine rpm.

(3) Driving and stopping

- Check to see that the specified pressure is obtained when engaging the clutch.
  The pressure may drop slightly at low engine rpm, but it does not affect the operation of the engine.
- When attempting to change gears for forward or reverse movement, first put the engine rpm at idle.
- The temperature of oil at operation must be 60 ~ 90°C.
- When attempting to stop the engine, be sure to place the control lever in the neutral position.

(4) Emergency bolt

The emergency bolt is designed to couple the clutch mechanically when the clutch indicates abnormal condition or slip at clutch coupling operation. The reverse clutch pack has no emergency bolt. When using the emergency bolt, first loosen the tightening bolts to remove the control block, tighten the 8mm wrench bolt on the forward disc pack using a 5mm L-shaped wrench, then reassemble the control block in the reverse order. Be sure to use this emergency bolt literally in case of emergency.



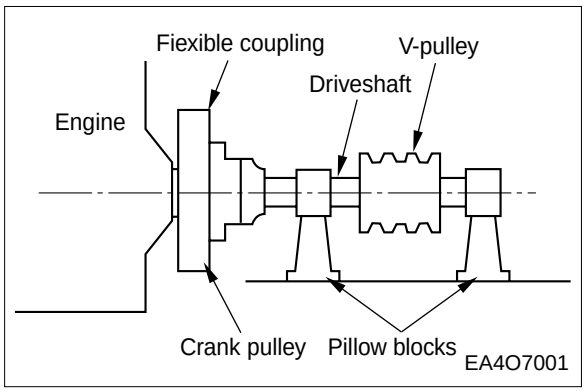
5.2. Front Power Take-Off (F.P.T.O)

5.2.1. For maximum FPTO power

For front power take-off in line with crankshaft, it is a standard procedure to support driveshaft and V-pulley by two pillow blocks by using flexile coupling for connection to engine.

When the front PTO is installed, be sure to take deflection reading. Radial run-out should be no more than 0.02 mm.

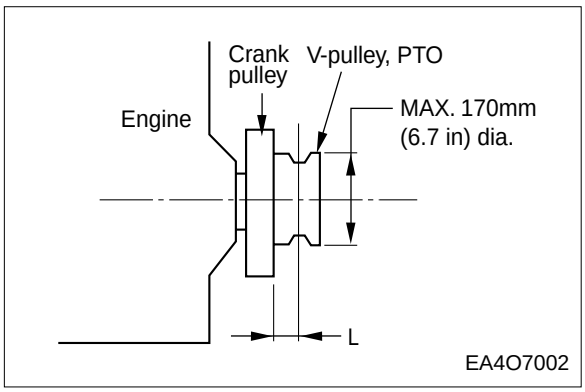
Be sure to limit the front PTO output within the maximum allowable horsepower as specified for each model. (Torque represents when there is no propeller load)



Model	Load(kW)	rpm		Model	Load(kW)	rpm
L136	60	1,600		L136TI	88	1,600
L136T	72	1,600		L086TI	105	1,600

5.2.2. For small cross drive power

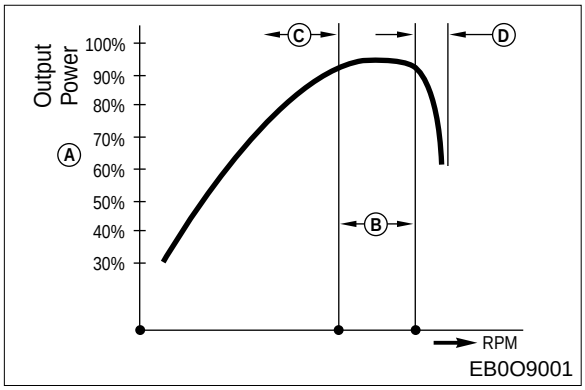
The figure is applicable to the drive arrangement (No supporting bearing on front side of PTO pulley) in which the distance between the end face of the engine pulley and the centerline through pulley groove is not greater than 60mm. The distance is indicated as L in the figure.



Model	L mm	Belt driven side load(kW)	rpm
L136	60	35	1,600
L136T		40	
L136TI		50	
L086TI		62	

5.3. Propeller Selection

Your dealer has chosen a propeller designed to deliver top performance and economy under most conditions. To obtain the maximum percentage of available horsepower (A), the engine RPM at Full Throttle should be in the specified Full Throttle Operating Rage (B). Refer to Specifications in Performance Curve.



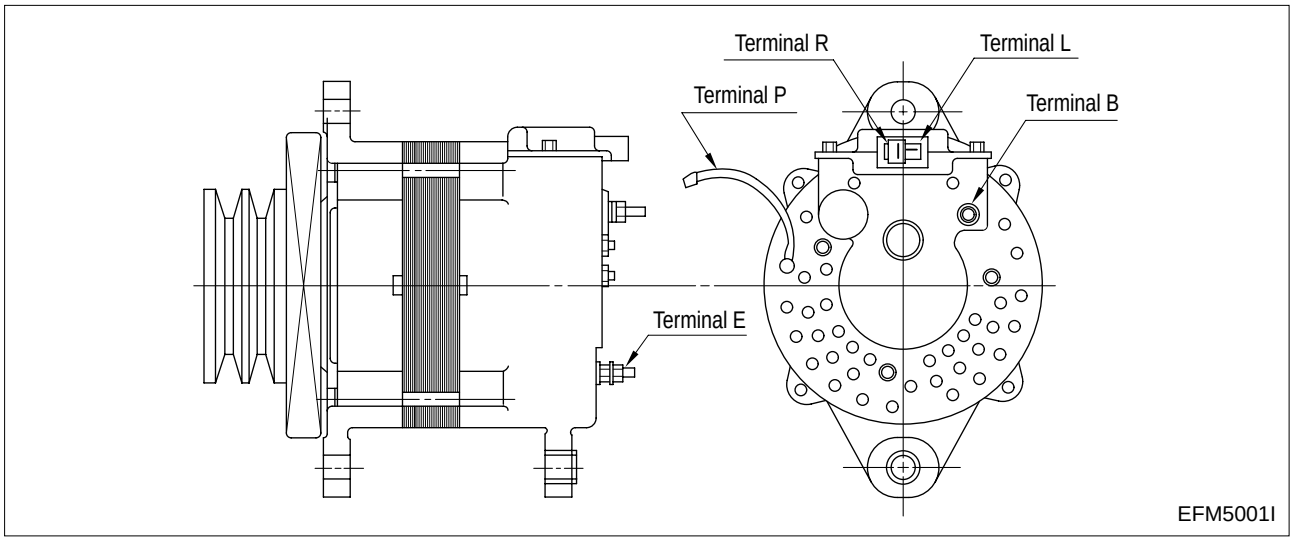
If the engine's full throttle RPM on normal load is below the specified on the low side of the range (C), use a propeller with less pitch to increase the RPM. Should the engine's full throttle RPM want to exceed the specified range (D), the engine RPM is limited by the governor. Use a propeller of higher pitch to stop the limiting by the governor.

Note : Engine damage can result from incorrect propeller selection which:

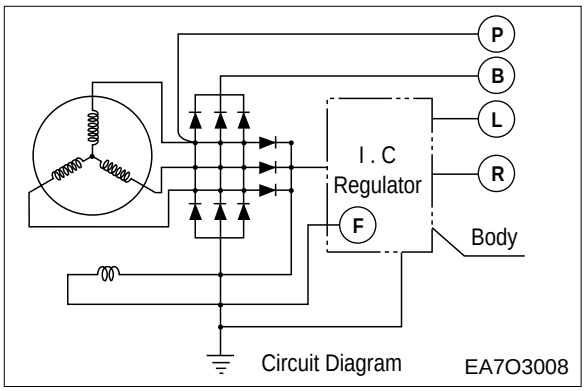
- (C) Prevents engine RPM from attaining the specified "Full Throttle Operating Range". Engine is laboring, install lower pitch propeller.
- (D) Allows engine RPM above the specified "Full Throttle Operating Range". Engine RPM is limited by the governor, install a higher pitch propeller.

5.4. Electric System

5.4.1. Alternator



The alternator is fitted with integral silicon rectifiers. A transistorized regulator mounted on the alternator limits the alternator voltage evenly. The alternator should be operated with the regulator and battery connected in circuit to avoid the damage of the rectifier and regulator.
The alternator is maintenance free, but it must be protected against dust and above all against moisture therefore it must be mounted a cover for protector properly.



(1) Inspection Point (In case of abnormal charging)

● Voltage measurement between terminal and alternator body during operation.

<Voltage during operation>

Measuring point	Voltage
Terminal B - Body	about DC28V ~ 29V
Terminal L - Body	about DC28V ~ 29V
Terminal R - Body	about DC28V ~ 29V

<Voltage during stop>

Measuring point	Voltage
Terminal B - Body	about DC24V
Terminal L - Body	about DC2V
Terminal R - Body	about DC24V

For the confirmation of wiring state, measurement of voltage should be carried out only at each terminal during engine stop.

● **Inspection points on the voltage regulator**

<Resistance value between voltage regulator's terminals>

Terminal		Resistance Value (KΩ)
+	-	
L	E	about 2
R	E	about 53
F	E	about 50
L	F	about 50
R	L	about 50
R	F	about 168

Terminal		Resistance Value (KΩ)
+	-	
E	R	∞
L	R	∞
F	R	∞

(2) Precautions in use

- Pay attention to dropping the battery voltage capacity when they are left for long time even without use.
- In cold winter season, for the starting may not be done well sometime, do not try it to be continuous immediately but try to start again after waiting about 30 seconds.
- Prior to operating the gauge panel, make sure of the polarity of battery once again (In general, red side means "+" and black one is "-".)
- Disassembling the gauge panel may be accompanied with a risk of electrical shock, First detach the cable from the connector at the rear side of the gauge panel without fail, then disassemble it.
- If metallic foil is used for safety connector instead of the cut-off fuse, excessive current that can make serious damage might flow into the electric parts of the engine. (Never do this!) If cutting off of fuse is occurred, solve the problem, then replace it with a new fuse.
- Since battery has a danger of explosion by a heat, it must not be installed at the place where there generates a lot of heat.
- When engine is in stop, always pull out the key. Then a hazard of fire or wound due to wrong operation may not happen.
- In case of scrapping the batteries, observe the followings.

NOTE : *Do not throw it in the fire to scrap. It should not be thrown away into the places where are liable to cause the environmental pollution such as stream, river and mountain. Pack them as far as possible and dispose it as rubbish that is unable to use again.*

- DAEWOO will not be responsible to the problems that might be raised by the disassembling and structural change of this product without consultation.

5.4.2. Starter Motor

The starter motor is installed on the flywheel housing.

When the starter key switch is turned on, the starter motor pinion flies out and engages the ring gear of the flywheel. Then the main contact is closed, current flows, and the engine is started.

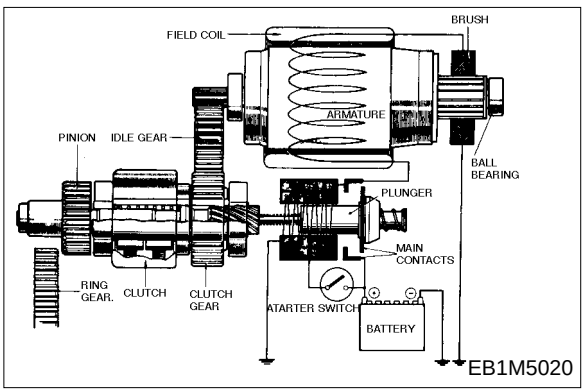
After the engine starts, the pinion automatically returns to its initial position as soon as the starter key switch is released.

Otherwise, the starter motor may be damaged or burned out.

In case of repairing the engine, dip the pinion of the starter and ring gear into the new fuel, then remove the dirty or corrosion with a brush.

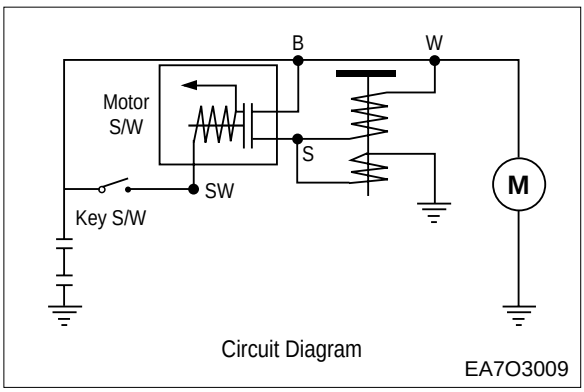
After that, apply the grease on them to protect the corrosion.

Whenever you clean the starter, always pay attention not to occur the electric short due to entering the water.



Starter motor always should be protected from humidity.

Precaution : Before the maintenance of the electric system, be sure to detach the battery wire (-) to avoid the electric short.



6. Disassembly and Assembly of Major Components

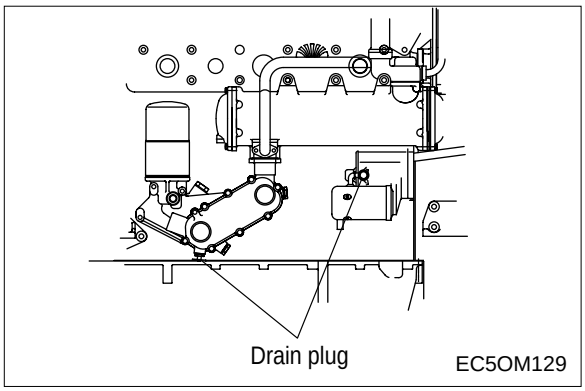
6.1. Disassembly

6.1.1. General precautions

- Maintenance operation should be carried out in a bright and clean place.
- Before disassembly, provide racks for arrangement of various tools and disassembled parts.
- Arrange the disassembled parts in the disassembly sequence and use care to prevent any damage to them.

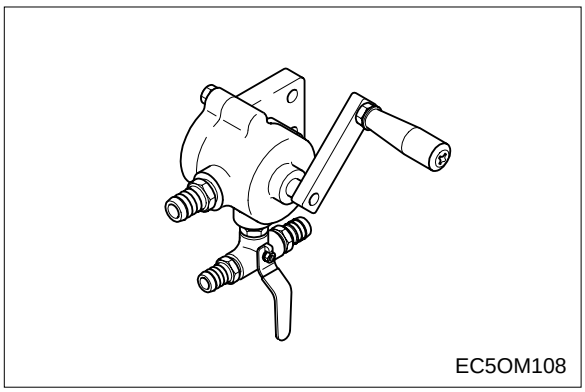
6.1.2. Cooling water

- Remove the drain plug from the cylinder block and under side of oil cooler, then drain out the cooling water into a container.



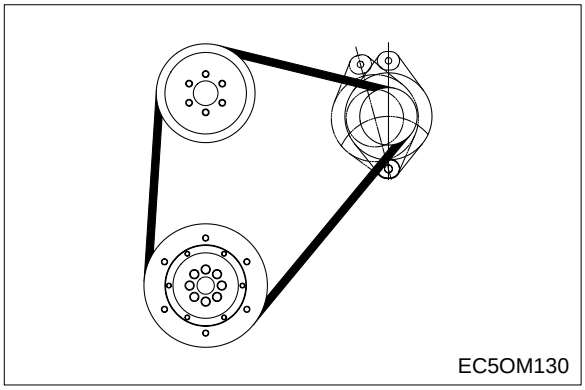
6.1.3. Engine oil and drain pump

- Drain out the engine oil into a container using oil drain pump.
- Remove the oil hose from oil pan and reduction gear.
- Unscrew the oil drain pump fixing bolts and disassemble the oil drain pump.



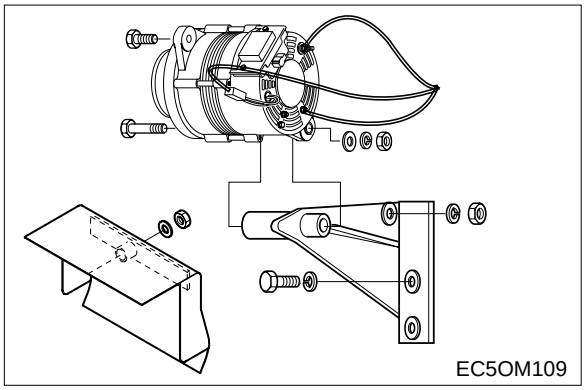
6.1.4. V - belt

- Loosen the tension adjusting nut installedon the alternator support, and take off the V -belt.



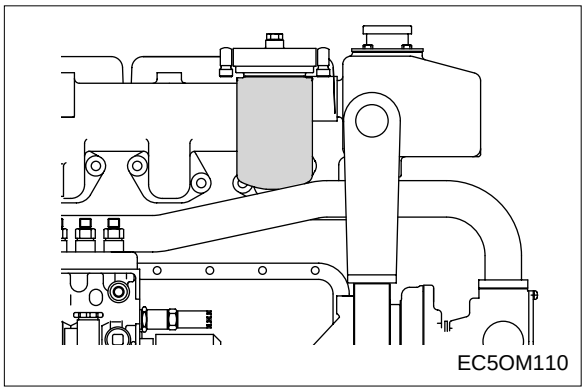
6.1.5. Alternator

- Remove the electric wires and the alternator fixing bolt and then disassemble the cover and alternator.
- Remove the tension adjusting bolt and bracket.


EC5OM109

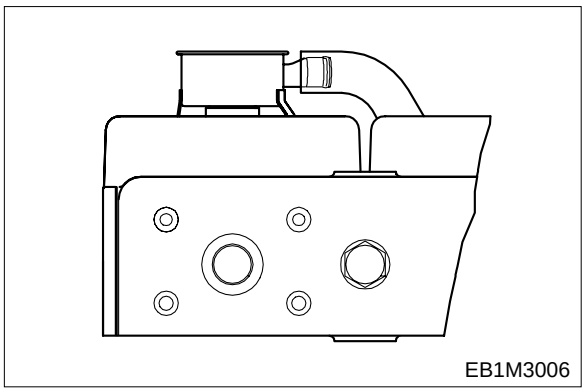
6.1.6. Fuel filter

- Remove fuel hoses connected to the fuel injection pump, take off the filter housing fixing bolts, then disassemble the fuel filter.


EC5OM110

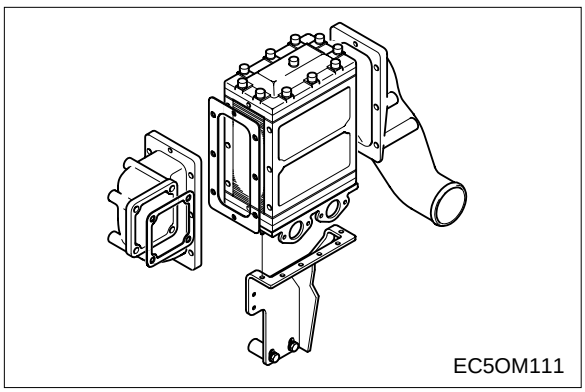
6.1.7. Breather

- Loosen the clamp screw to remove the rubber hose and the breather after unscrew.


EB1M3006

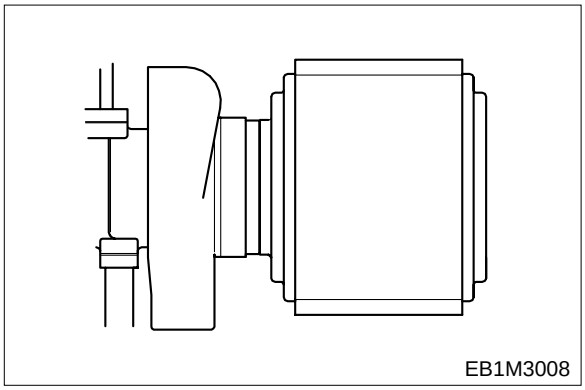
6.1.8. Inter cooler

- Remove the cooling water pipe from inter cooler to marine gear oil cooler.
- Remove the air pipe connected to intake manifold and turbocharger.
- Disassemble the intercooler after unscrew the mounting bolts on the heat exchanger.


EC5OM111

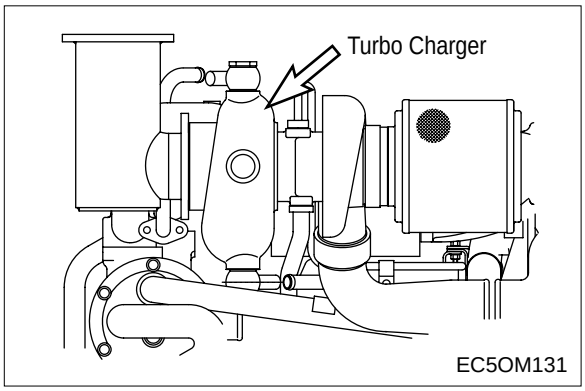
6.1.9. Air cleaner

- Remove the air filter element.
- Loosen the clamp, then remove the air cleaner.



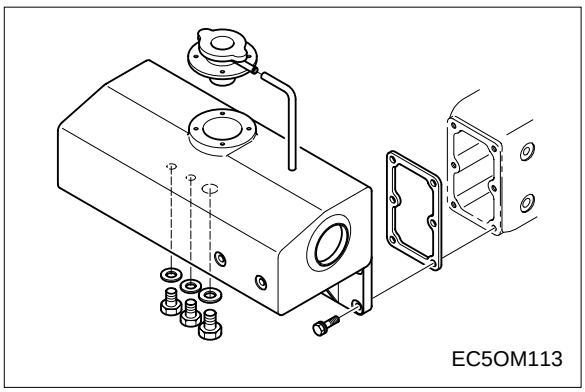
6.1.10. Turbo charger

- Loosen the clamp screw of the rubber hose connected to the inter cooler, and take off the intake pipes both simultaneously.
- Unscrew the exhaust pipe flange fixing bolts and the nuts installed on theturbocharger, then take out the exhaust pipe.
- Remove the turbocharger after removing the oil supply pipe and return pipe including both inlet and outlet cooling water pipes.



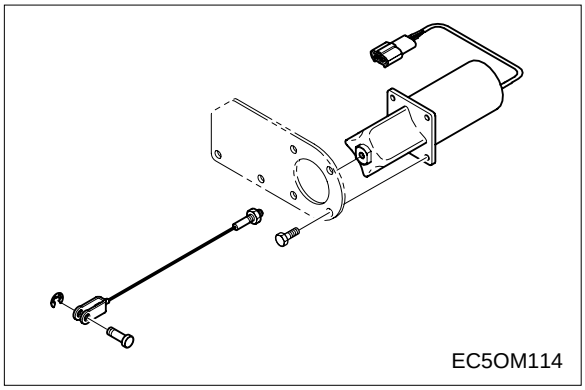
6.1.11. Expansion tank

- Remove the reservoir tank and hoses connected to the expansion tank.
- Loosen the expansion tank bracket fixing bolts then remove the expansion tank.



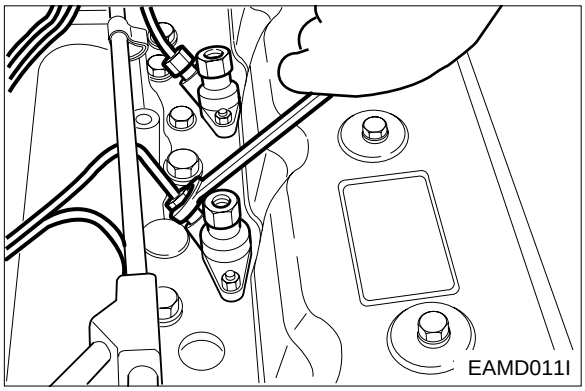
6.1.12. Stop solenoid

- Remove the cable from the fuel stop lever to the stop solenoid.
- Disassemble the stop solenoid.


EC5OM114

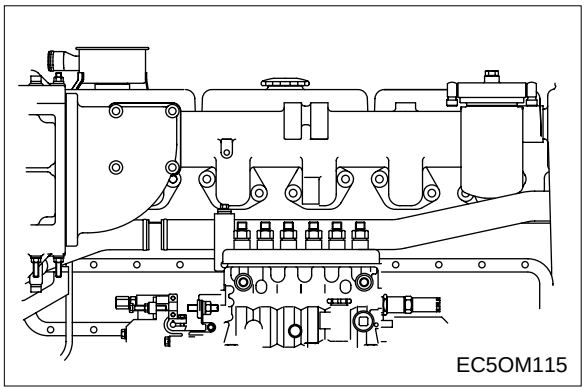
6.1.13. Injection pipe

- Unscrew the hollow screws to disassemble the fuel return pipe.
- Remove the nuts installed on the fuel injection pump and the injection nozzles, then disassemble the injection pipe.


EAMD011I

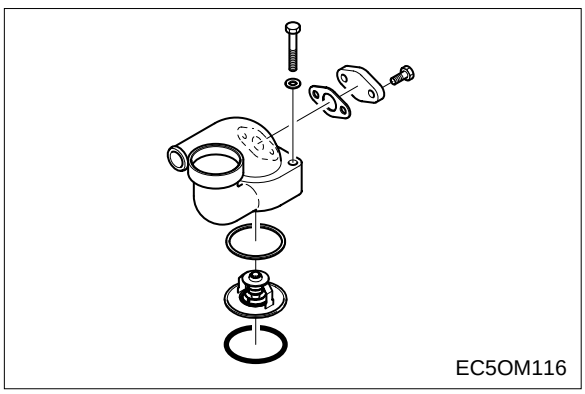
6.1.14. Intake manifold

- Remove the hoses connected to the injection pump and fuel filter and intake manifold.
- Loosen the intake manifold fixing bolts, then disassemble the intake manifold.


EC5OM115

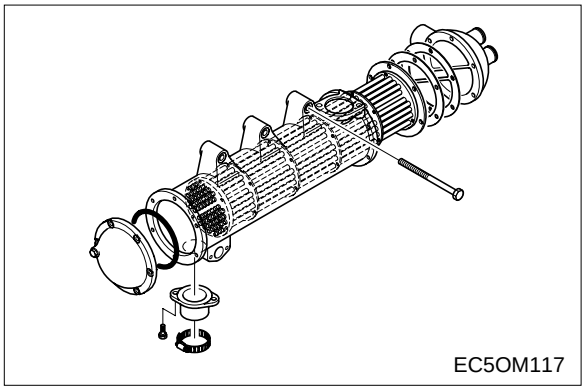
6.1.15. Thermostat

- Release the hose clamps connected to the both portion of the heat exchanger and cooling water pipe
- Remove the thermostat housing assembly, and unscrew the mounting bolts, then take off two thermostats.


EC5OM116

6.1.16. Heat exchanger

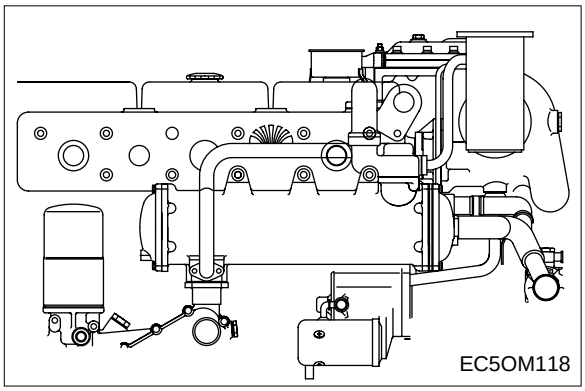
- Loosen the clamp on the rubber hoses connected to the inter cooler and cooling water pipe of the heat exchanger, and remove the inter cooler then take off the rubber hoses.
- After remove the inter cooler, unscrew the heat exchanger fixing bolts, then detach the heat exchanger.


EC5OM117

6.1.17. Exhaust manifold

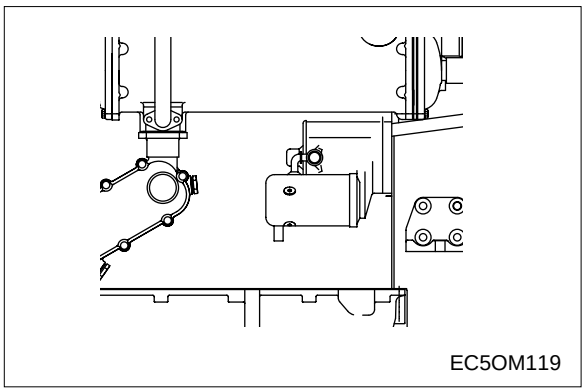
- Remove the cooling water pipes on the front and upper side and then exhaust outlet pipe.
- Unscrew the exhaust manifold fixing bolts, and then detach the exhaust manifold and gaskets.

Caution : The exhaust manifold is very heavy.
Be careful to handle it.


EC5OM118

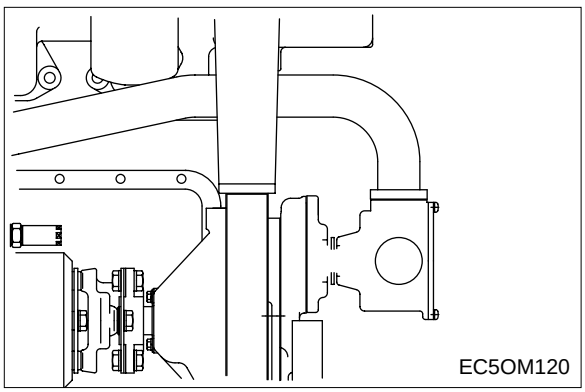
6.1.18. Starter

- Unscrew the starter fixing bolts, then disassemble the starter.


EC5OM119

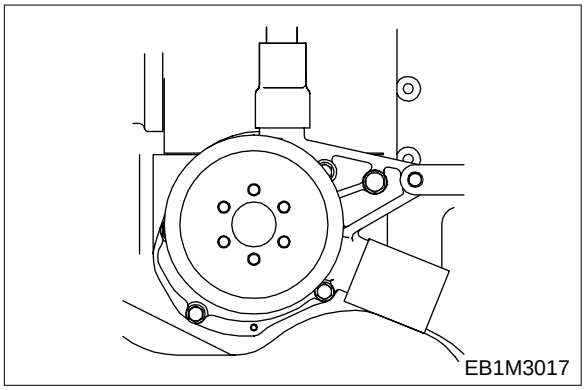
6.1.19. Sea water pump

- Release the clamp on the rubber hose connected to the sea water pipe then detach the rubber hose.
- Unscrew the sea water pump fixing bolts, then remove the sea water pump.


EC5OM120

6.1.20. Water pump

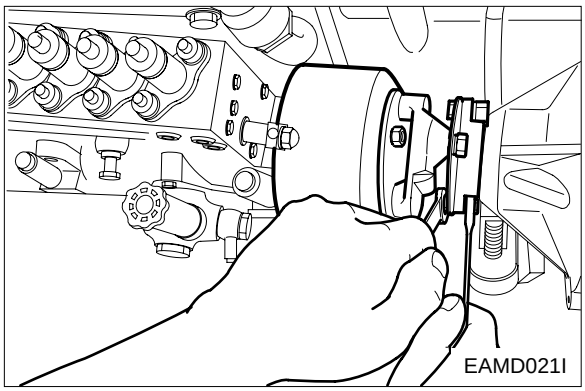
- Remove the expansion tank and rubber hose connected to the expansion tank.
- Remove the water pipe and hoses connected to the oil cooler.
- Unscrew the water pump fixing bolts and remove the water pump.



6.1.21. Injection pump

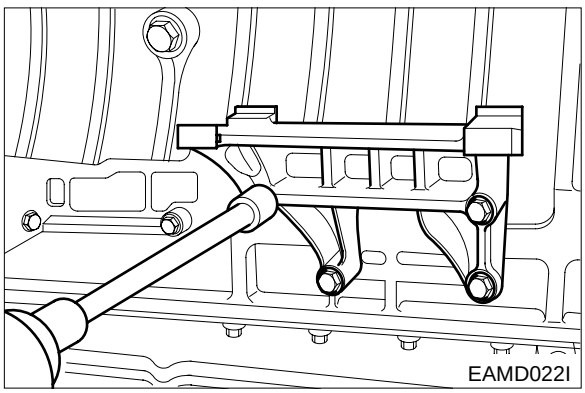
(A) L086TI

- Remove the oil supply pipe and the return pipe connected to the fuel injection pump.
- Unscrew the bolts connected the coupling and drive shaft, disassemble the injection pump mounting bolts, then detach the injection pump.



Note : After letting No.1 cylinder to the 'OT' position by turning the crankshaft, disassemble the injection pump.

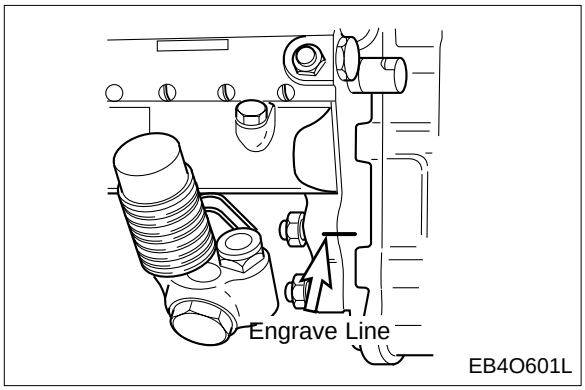
- Unscrew the pump bracket fixing bolts to detach the bracket from the cylinder block.



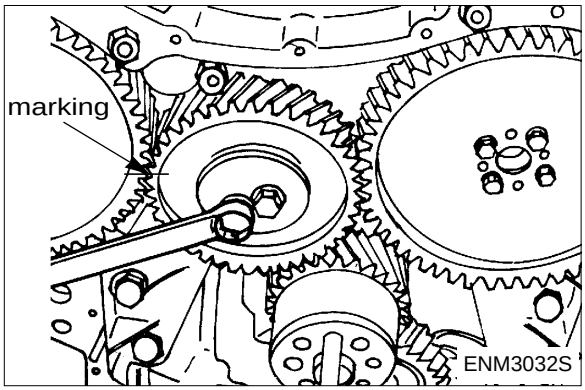
Note : Do not mix the disassembled shims. They should be reassembled to the original position.

(B) L136/T/TI

- Put the piston (No.1) of the engine to O.T position, then remove the timing gear case cover, and engrave a line on the both flanges as the figure. (This is only for no engraved line before.)
- Remove the injection pump,

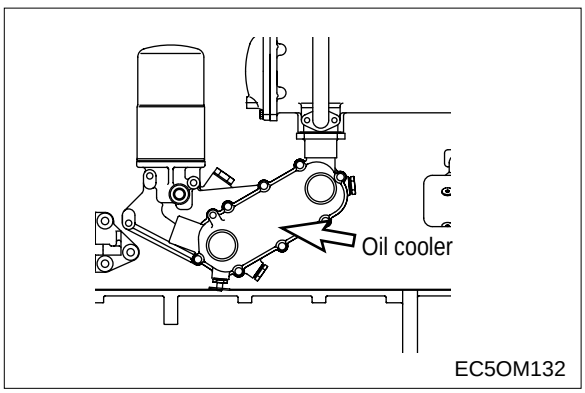


To exchange the injection pump for new one, put the piston (No.1) of the engine to O.T position, then mark the line temporary by using oil paint at the geared point between injection pump gear and idle gear separately.
This marking is used to assemble the injection pump gear to reassemble the new injection pump. (Refer to 6.3.27. (b).)



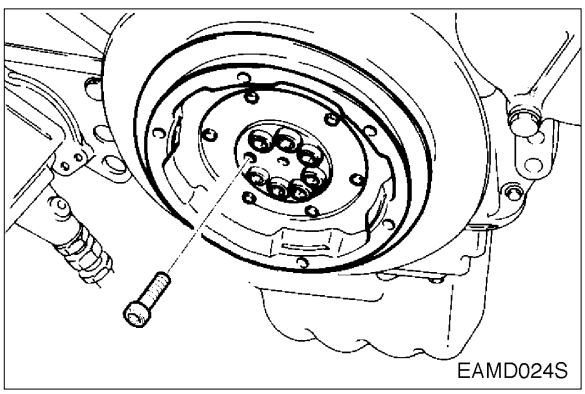
6.1.22. Oil filter

- Detach the pipes connected to the water pump and heat exchanger. Remove the oil filter cartridge using a filter wrench.
- Unscrew the oil filter fixing bolts and detach the oil filter and cooler assembly from the cylinder block.



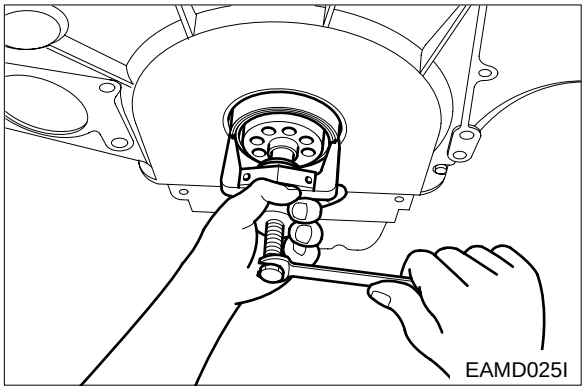
6.1.23. Vibration damper

- Unscrew the pulley fixing bolts and disassemble the pulley-vibration damper assembly.
- Unscrew the vibration damper fixing bolts and detach the damper from the pulley.



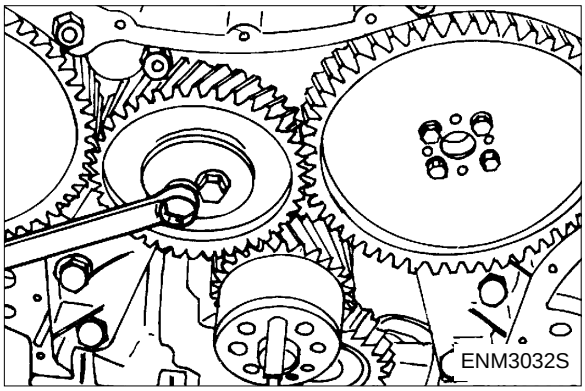
6.1.24. Timing gear case cover

- Disassemble the oil seal using the removing jig.
- Unscrew the cover fixing bolts and disassemble the cover from the timing gear case.



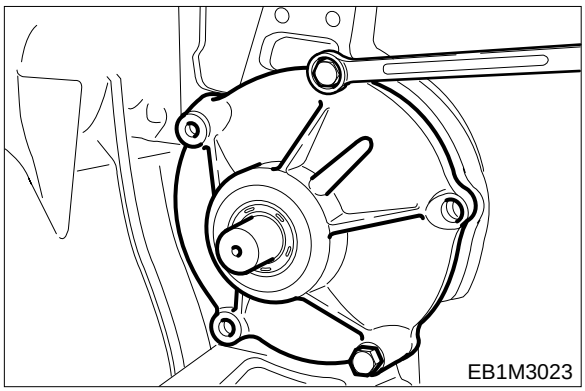
6.1.25. Idle gear

- Unscrew the idle gear fixing bolts and disassemble the thrust washer and idle gear.
- Disassemble the idle gear pin using a rubber hammer to prevent them from damaging.



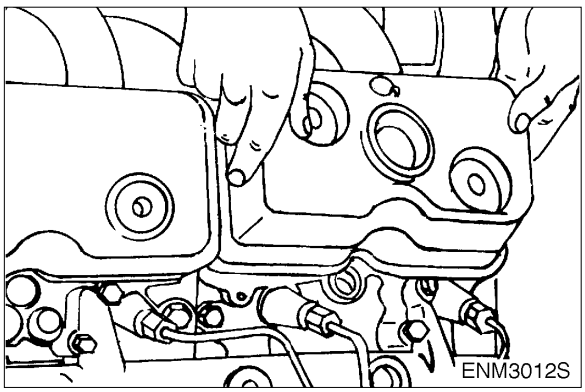
6.1.26. Injection pump drive

- Unscrew the drive shaft bearing housing fixing bolts and remove the injection pump drive assembly like as the shaft, gear, bearings, and housing are put together.



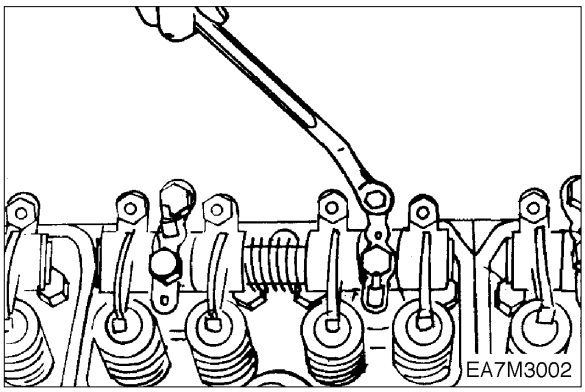
6.1.27. Cylinder head cover

- Unscrew the head cover fixing bolts and disassemble the cover.
- Keep the bolts in an assembly state so that the packing and washers may not be lost, and keep the cover packing as assembled with the cover.

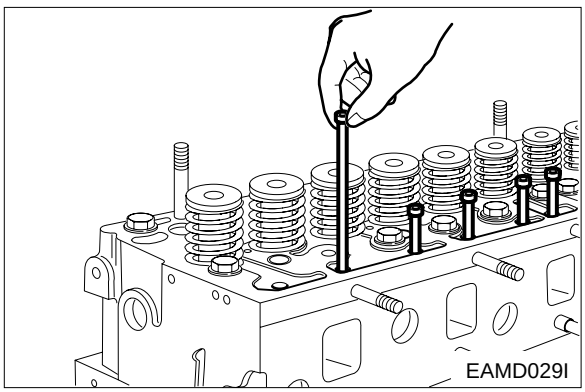


6.1.28. Rocker arm assembly

- Unscrew the rocker arm bracket bolts and remove the rocker arm assembly.
- Take off the snap rings to remove the washers and rocker arm, then unscrew the bracket fixing bolts to take off the bracket and springs.



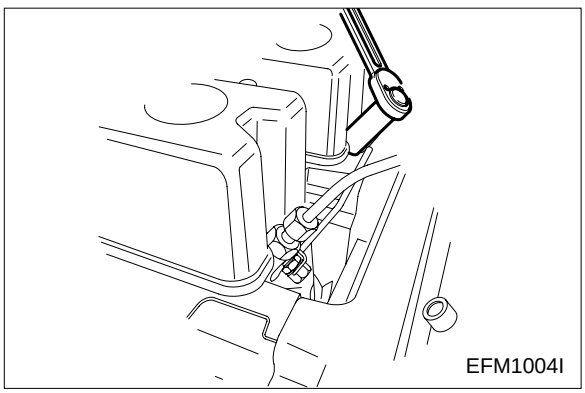
- Take out the push rods.



6.1.29. Injection nozzle

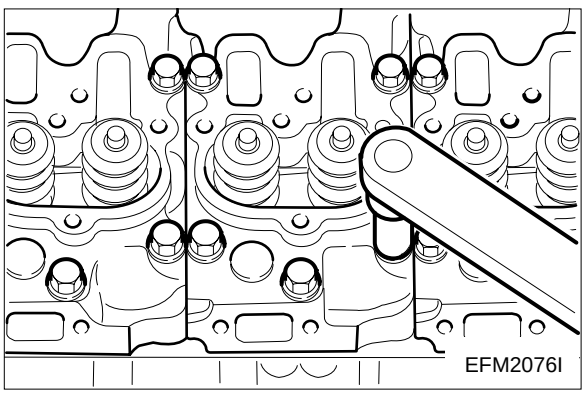
- Take off the injection pipes between the injection pump and injection nozzles.
- Remove the nozzle holder assembly using the nozzle removing jig.

Do not disassemble the injection nozzle unless coolant or gas comes out.



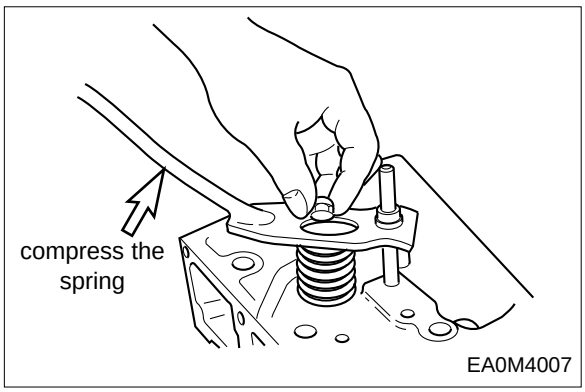
6.1.30. Cylinder head

- Unscrew the cylinder head fixing bolts and take off the cylinder heads.
- Remove the cylinder head gaskets.



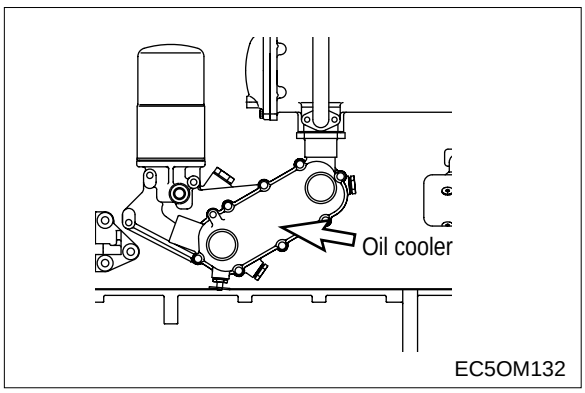
6.1.31. Valve & stem seal

- Compress the valve spring retainer using a jig and take off the valve cotter pins.
- Disassemble the valve springs and retainers.
- Take off the valves.
- Remove and discard the used valve stem seals in order not to be re-used.



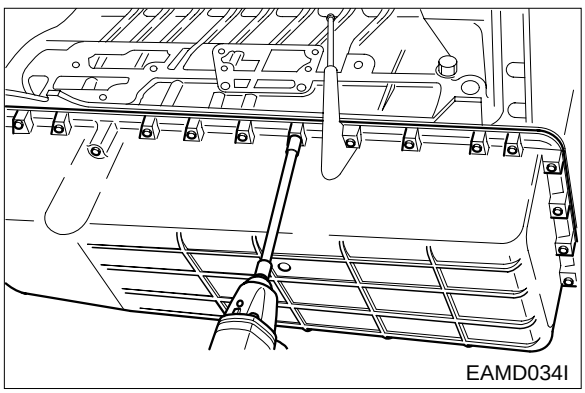
6.1.32. Oil cooler

- Unscrew the oil cooler cover fixing bolts and disassemble the oil cooler tube assembly from the oil cooler housing.



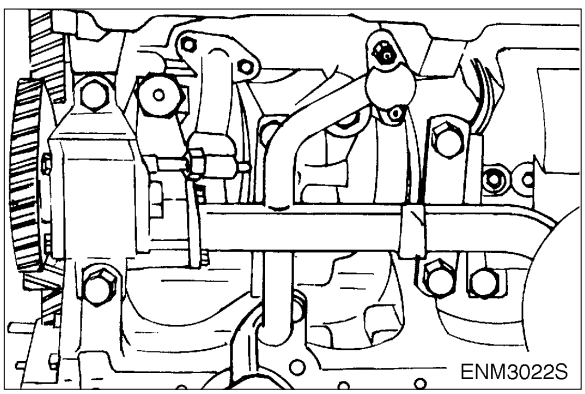
6.1.33. Oil pan

- Stand the engine up the flywheel housing end face towards the bottom side.
- Release the oil pan fixing bolts, then disassemble the oil pan.



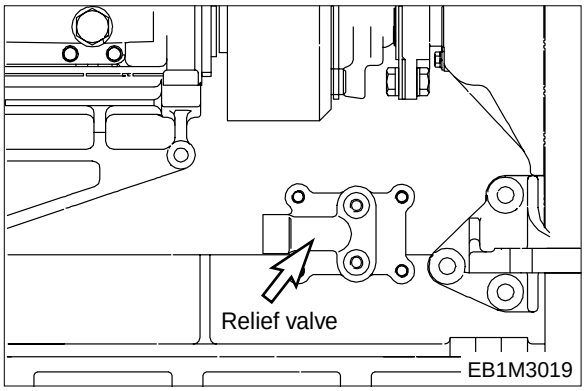
6.1.34. Oil pump & oil pipe

- Unscrew the oil suction pipe bracket bolts, releasing the pipe fixing bolts, then detach the oil suction pipe assembly.
- Disassemble the oil pipes connected the oil pump to the cylinder block.
- Unscrew the oil pump fixing bolts and disassemble the oil pump.



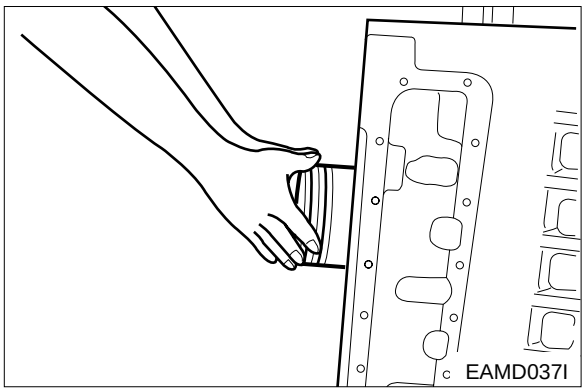
6.1.35. Relief valve

- Unscrew the relief valve housing fixing bolts
- Disassemble the relief valve from the housing.

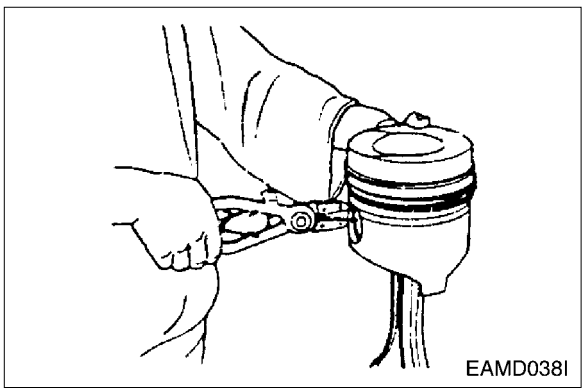


6.1.36. Piston and connecting rod

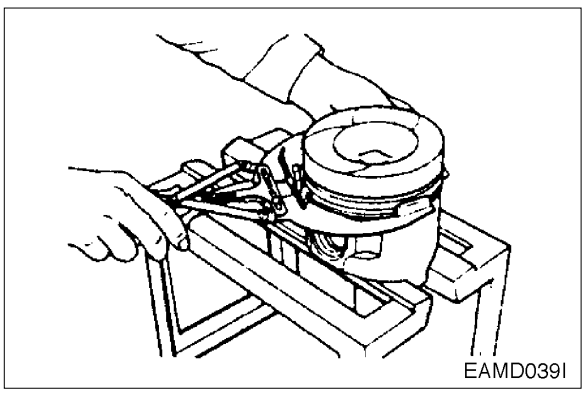
- Disassemble the pistons by two cylinders while turning the crankshaft.
- Unscrew the connecting rod fixing bolts and take off the pistons and connecting rods in the direction of piston upper side.



- Remove the piston pin and snap rings, then disconnect the connecting rod from the piston.

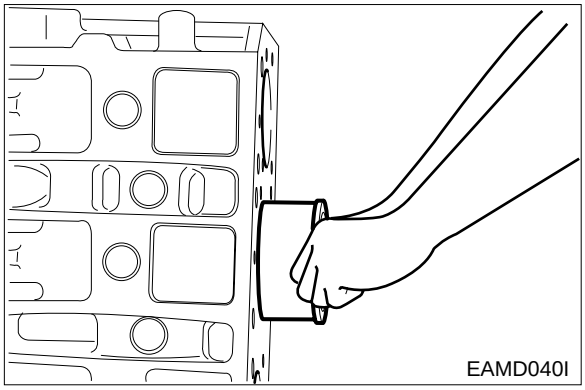


- Disassemble the piston rings using a ring pliers.
- Arrange the disassembled parts carefully in order not to interchange each other and keep them in the sequence of cylinder number.



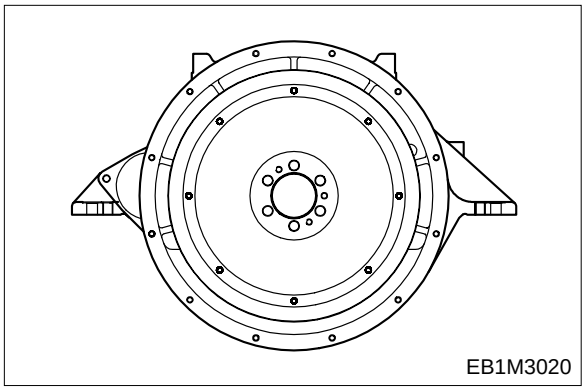
6.1.37. Cylinder liner

- Take off the cylinder liner.



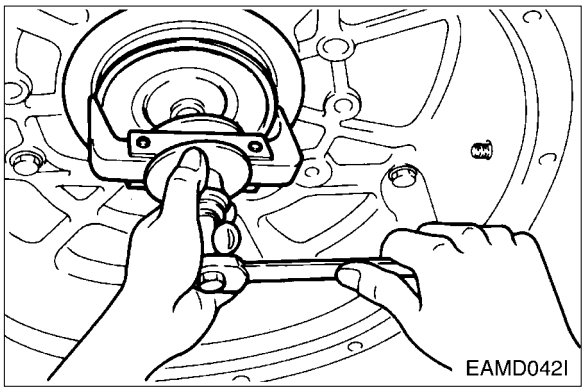
6.1.38. Flywheel

- First remove two fixing bolts of the flywheel and install the two dowel pins in the bolt hole.
- Unscrew the last flywheel fixing bolts, and then detach the flywheel with care.



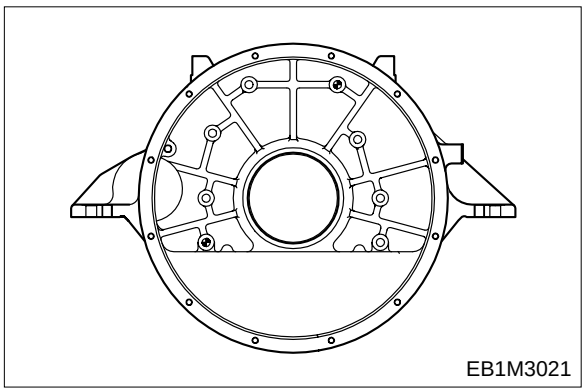
6.1.39. Oil seal

- Take off the rear oil seal using an oil seal disassembling jig.



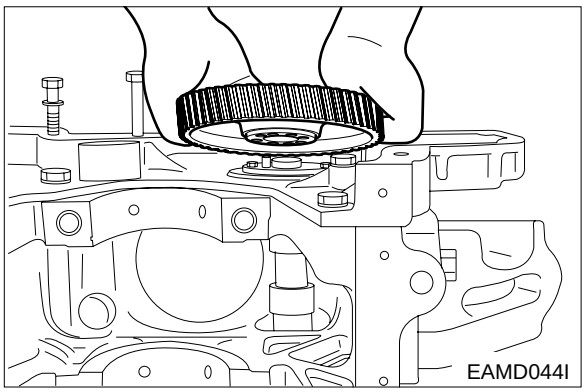
6.1.40. Flywheel housing

- Loosen the housing fixing bolts, then disassemble the flywheel housing.



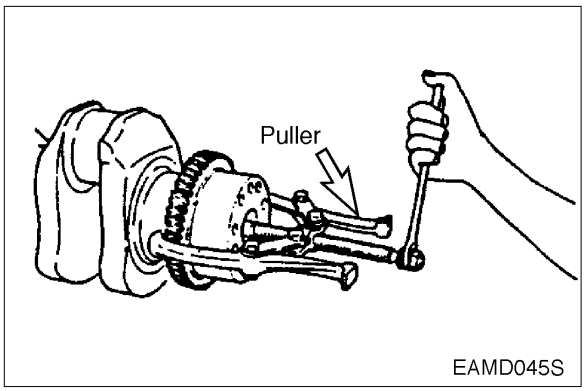
6.1.41. Cam shaft and tappet

- Remove the camshaft gear and thrust washer.
- Take out the camshaft with care not to damage it and inner bearings.
- Take out the tappets by hand.



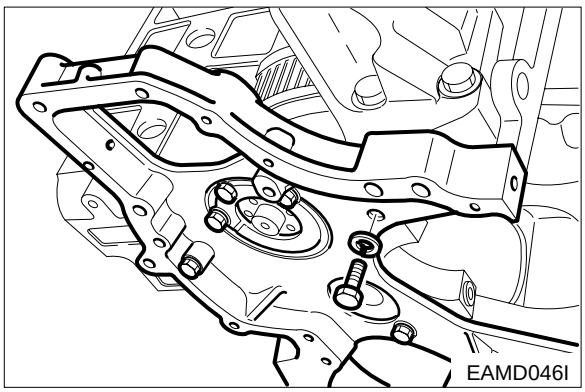
6.1.42. Crankshaft gear and oil pump idle gear

- Loosen the socket head bolts and take out the oil pump idle gear.
- Use a puller of special tool to remove the crankshaft gear.



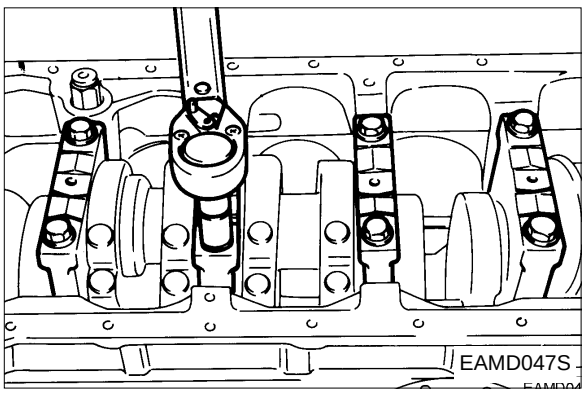
6.1.43. Timing gear case

- Unscrew the case fixing bolts and disassemble the timing gear case.



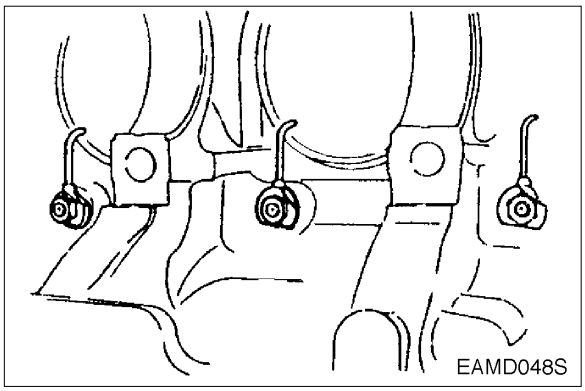
6.1.44. Crankshaft and bearing cap

- Unscrew the main bearing cap fixing bolts and remove the bearing caps.
- Take off the crankshaft.
- Detach the main bearings.



6.1.45. Oil spray nozzle

- Unscrew the fixing bolt and remove the oil spray nozzles.



6.2. Inspection

6.2.1. Cylinder block

1) Clean the cylinder block thoroughly and check a visual inspection for cracks or damage.
2) Replace if cracked or severely damaged, and correct if slightly damaged.
3) Check the oil and water passing lines for restriction or corrosion.
4) Make a hydraulic test to check for any cracks or air leaks.

Hydraulic test : Stop up each outlet port of water and oil passages in the cylinder block, apply air pressure of about 4 kg/cm^2 against the inlet ports, then immerse the cylinder block in water for about 1 minute to check any leaks. (Water temperature: 70°C)

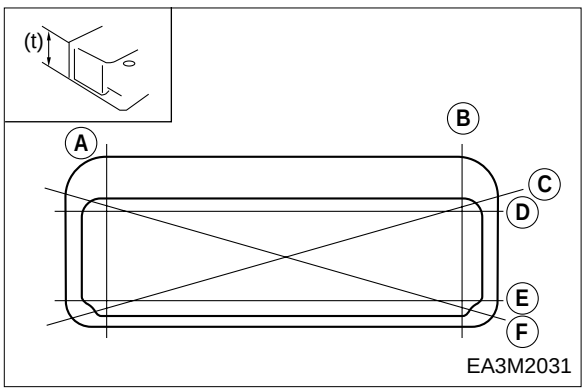
6.2.2. Cylinder head

1) Inspection of cracks and damage

- Carefully remove carbon from the lower face of the cylinder head using nonmetallic material to prevent scratching of the valve seat faces.
- Check the entire cylinder head for very fine cracks or damage invisible to ordinary sight using a hydraulic tester or a magnetic flaw detector.

2) Distortion at the lower face

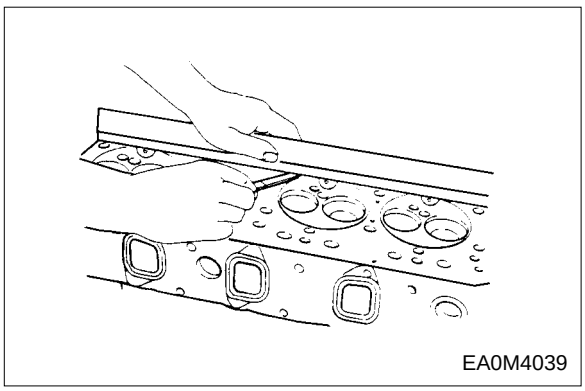
- Measure the amount of distortion using a straight edge and a feeler gauge at six positions as shown in the right figure.
- If the measured value exceeds the standard value, retrace the head with grinding paper of fine grain size to correct such defects.
- If the measured value exceeds the maximum allowable limit, replace the cylinder head.



EA3M2031

<Lower face warp and height>

	Standard	Limit
Warp	0.2 mm or less	0.3 mm
Thickness : t (reference)	109.9 ~ 110.1 mm	108.4 mm


EA0M4039

3) Flatness

Measure the flatness of the intake and exhaust manifold face mounted on the cylinder head using a straight edge and a feeler gauge.

Standard	Limit
0.05 mm	0.2 mm

4) Hydraulic test

Hydraulic test for the cylinder head is same as that for cylinder block.

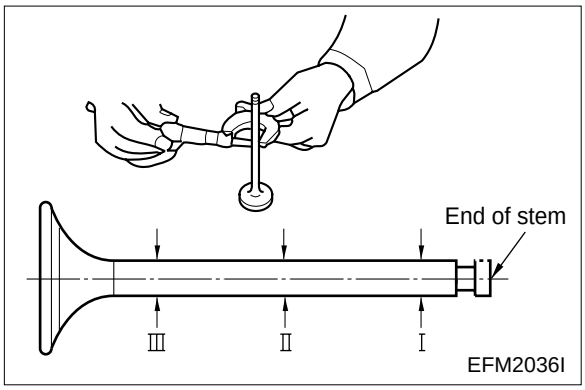
6.2.3. Valve & valve guide

1) Valve

Clean the valves with clean diesel oil, then inspect them as follows :

● **Valve stem outer diameter**

Measure the valve stem outer diameter at 3 positions (top, middle, and bottom). If the amount of wear is beyond the limit, replace the valve.



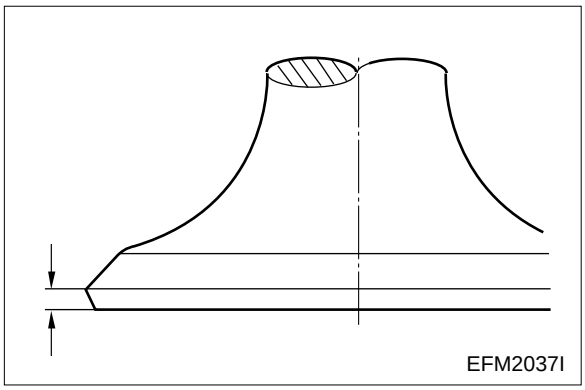
Dimension / Description	Standard	Limit
Intake valve stem	∅8.95 ~ ∅8.97 mm	∅8.93mm
Exhaust valve stem	∅8.935 ~ ∅8.955 mm	∅8.91 mm

● **Valve seat contacting faces**

Check the valve seat contacting face for scratch or wear, and correct the faces with fine grinding paper as necessary. Replace if severely damaged.

● **Valve head thickness**

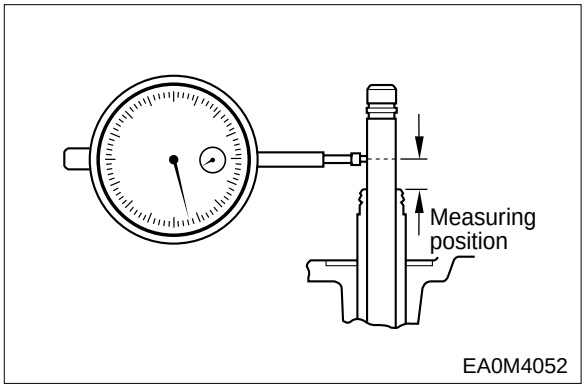
Measure the valve head thickness, and replace the valve if the measured value is beyond the limit.



Dimension / Description	Standard	Limit
Intake valve	2.7 mm	1 mm or less
Exhaust valve	2.2 mm	1 mm or less

2) Valve guide

● Install the valve into the valve guide and measure the clearance between them by valve movement. If the clearance is excessive, measure the valve and replace either the valve or the valve guide, whichever worn more.



<Valve stem end play>

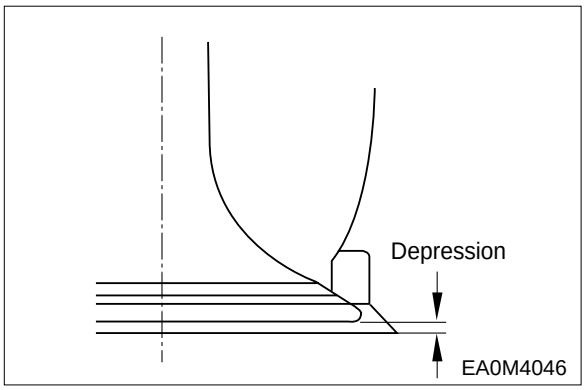
	Standard	Limit
Intake valve	0.030 ~ 0.065 mm	0.15 mm
Exhaust valve	0.045 ~ 0.080 mm	0.15 mm

● Install the valve into the cylinder head valve guide, then check and see if it is centered with the valve seat using a special tool.

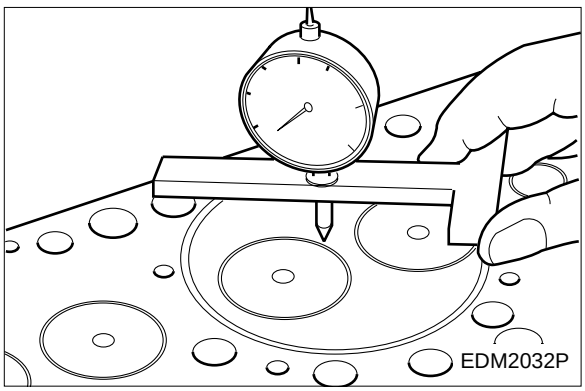
3) Valve seat

● **Contacting face amount**

Measure the contacting face between the intake valve seat and exhaust valve seat for valve seat wear, and replace if the measured value exceeds the specified limit.



● Install the valve into the valve seat on the cylinder head, and check the amount of depression of the valve from the lower portion of the cylinder head using a dial gauge.

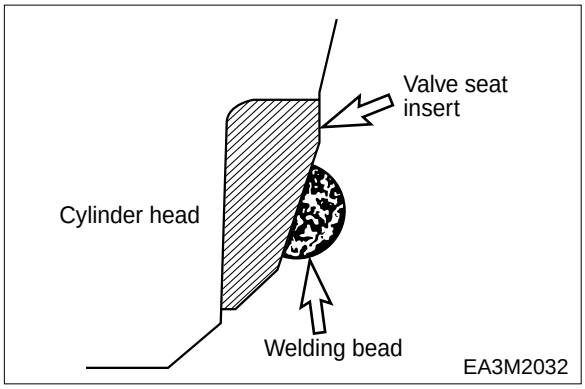


Valve Depression

	Standard	**Limit**
Intake &Exhaust	0~0.3 mm	0.55 mm

If the amount of depression is beyond the specified limit, replace the valve seat.

● For removal of the valve seat, apply arc welding work to two points of valve seat insert, and pull out the valve seat insert with inner extractor.



● For assembling of a new valve seat, by putting it among the dry ices of an ice box previously for about 2 hours for the cold shrinkage, and press it in the cylinder head by a special tool. (bench press)

● Apply the valve lapping compound on the valve head seating face and lap the valve seat by turning it until it is seated in its position, then wipe out the lapping compound.

Note : *Clean the valve and cylinder head with light oil or equivalent after the valve seat finishing is completed, and make sure that there are no grinding materials remained.*

4) Valve spring

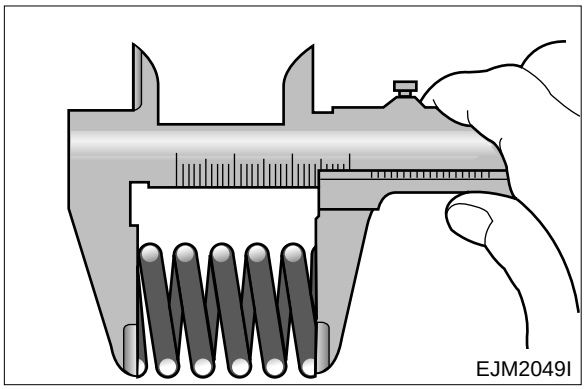
● **Visual check**

Visually check the exterior of the valve springs for damage, and replace if necessary.

● **Valve Spring Free Length**

Use a vernier caliper to measure the valvespring free length.

If the measured value is less than the specified limit, the valve spring must be replaced.

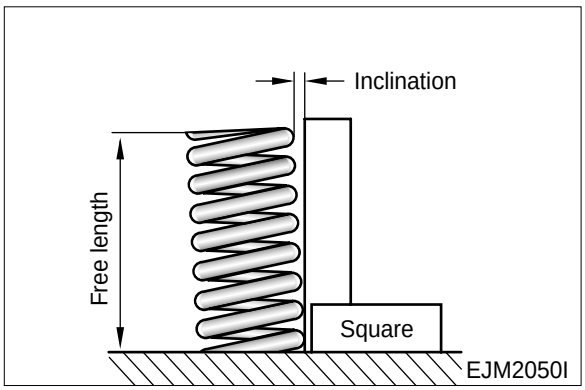


Spring free Length		Standard
Intake valve		64 mm
Exhaust valve	Inner	60 mm
	Outer	71 mm

● **Valve Spring Inclination**

Use a surface plate and a square to measure the valve spring inclination.If the measured value exceeds the specified limit, the valve spring must be replaced.

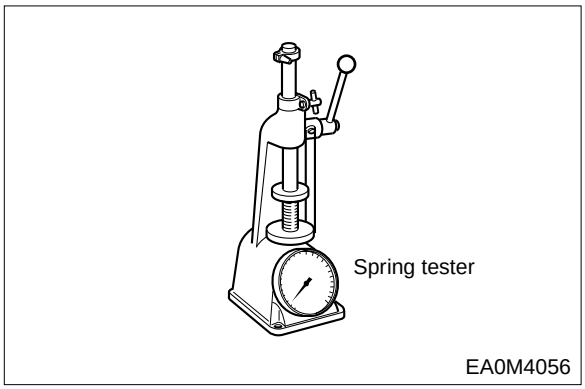
	Standard	Limit
Valve spring inclination	1.8 mm	2.7 mm



● **Valve Spring Tension**

Use a spring tester to measure the valve spring tension if the measured value is less than the specified limit, the valve spring must be replaced.

	Set Length		Spring force	Limit
Intake valve	Valve Spring Tension at 41mm Set Length		70 kg	± 3kg
Exhaust valve	Inner	38 mm	28.6 kg	± 6 %
	Outer	41 mm	66 kg	± 5 %



6.2.4. Rocker arm shaft assembly

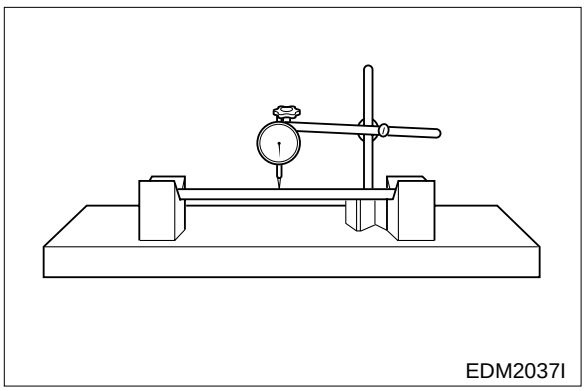
1) Rocker arm shaft

● **Rocker arm shaft run-out**

Place the rocker arm shaft on two V blocks and inspect the shaft for bending using a dial gauge.

If the amount of this run-out is small, press the shaft with a bench press to correct the run-out. Replace the shaft if the measured value exceeds the limit.

Limit	0.3 mm

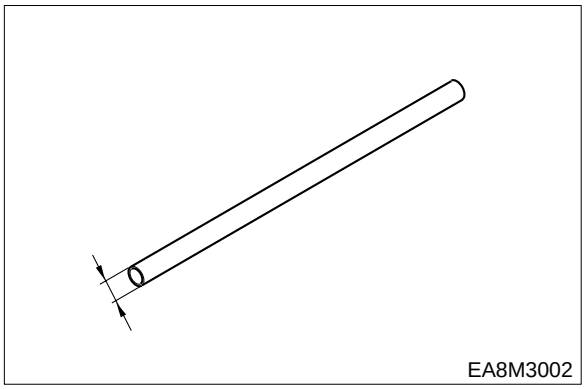


● **Rocker arm shaft diameter**

With an outside micrometer, measure the rocker arm shaft diameter at the point where the rocker arms have been installed.

Replace the rocker arm if the amount of wear is beyond the specified limit.

Standard	Limit
∅23.939 ~ ∅23.96 mm	∅23.75 mm


EA8M3002

2) Rocker arm

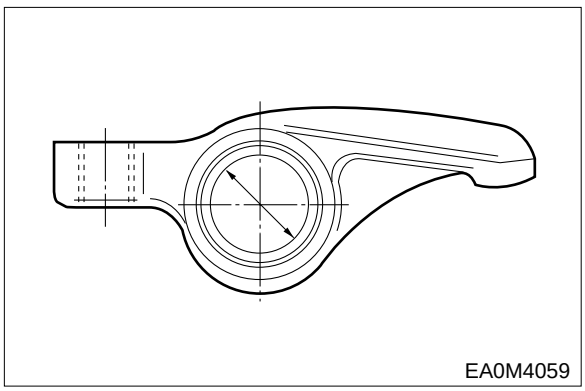
● **Visual check**

Visually check the face of the rocker arm in contact with the valve stem end for scores and step wear. If the wear is small, correct it with an oil stone or grinding paper of fine grain size. Rocker arm with a considerable amount of step wear should be replaced.

● **Diameter of the rocker arm bushing**

Measure the inside diameter of the rocker arm bushing with an inside micrometer or vernier calipers, and compare the measured values with the rocker arm shaft diameter. If the clearance exceeds the limit, replace either bushing or shaft, whichever worn more.

Standard	**Limit**
0.020 ~ 0.093 mm	0.25 mm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3) Tappet and push rod

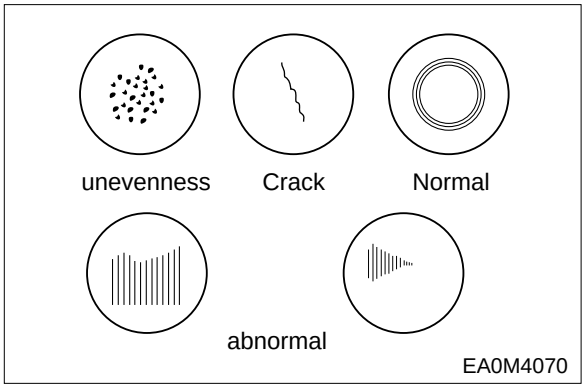
● **Clearance**

Measure the clearance of the tappet and tappet holes of the cylinder block. If the value is beyond the specified limit, replace the tappet.

Standard	**Limit**
0.035 ~ 0.077 mm	0.1 mm

● **Visual check of tappet**

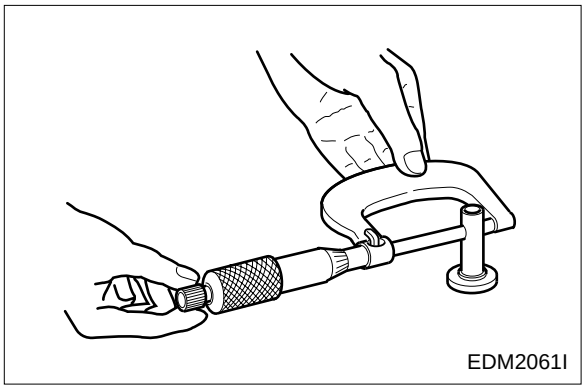
Visually check the face of the tappets in contact with the cam for pitting, scores or cracks, and replace if severely damaged. If the amount of cracks or pitting is small, correct with an oilstone or grinding paper.



● **Outside diameter**

With an outside micrometer, measure the tappet outside diameter. If the measured value is beyond the limit, replace tappets.

Standard	∅19.944 ~ ∅19.965 mm

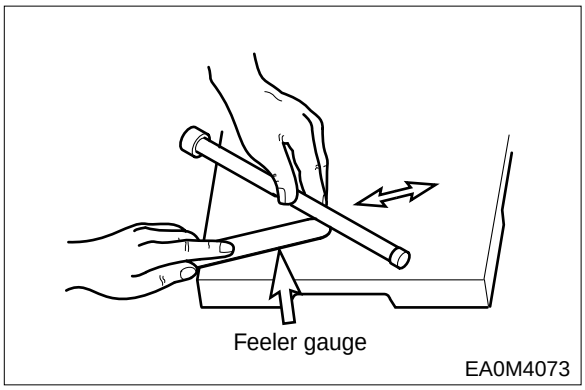


● **Push rod run-out**

Use a feeler gauge to measure the push rod run-out.

Roll the push rod along a smooth flat surface as shown in the figure.

Limit	0.3 mm or less



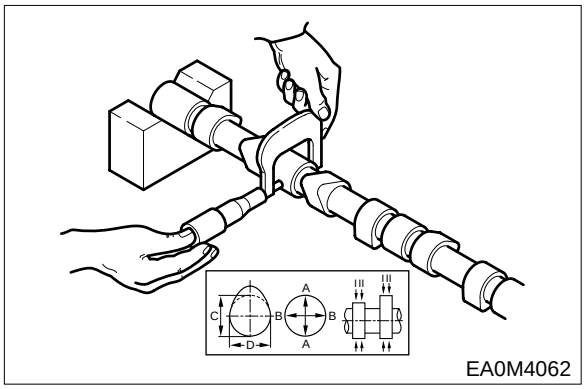
6.2.5. Camshaft

1) Cam

● **Cam lobe height**

Use a micrometer to measure the cam lobe height and journal diameter.

If the measured number is less than the specified limit, the camshaft must replaced.



EA0M4062

Items		Standard	Limit
Cam lobe height (C)	Intake	49.15 mm	48.85 mm
	Exhaust	49.32	49.00 mm
Cam journal diameter (A, B)		57.86 ~ 57.88 mm	57.52 mm

● **Cam surface**

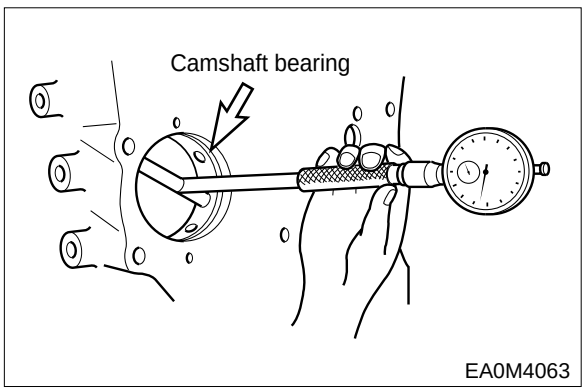
Inspect the cam surface for scratch or damage.

Slight step wear or damage on the cam surface may be corrected with an oilstone or oiled grinding paper. But, replace if severely damaged.

2) Camshaft

● **Clearance between camshaft journal and camshaft bush**

- With an outside micrometer, measure the camshaft journal diameter.
- Measure the inside diameter of the camshaft bush on the cylinder block using a cylinder bore indicator, and compare the measured value with the camshaft outside diameter to determine the clearance.



EA0M4063

<Clearance>

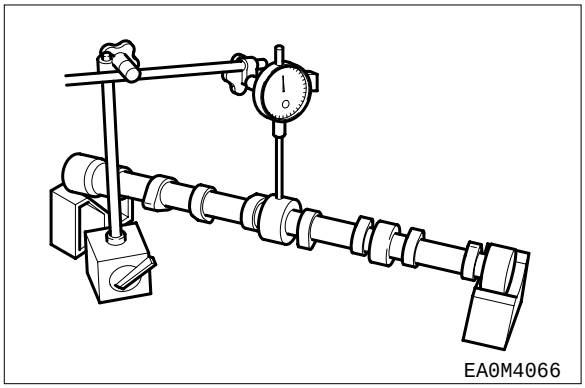
Standard	Limit
0.12 ~ 0.17 mm	0.24 mm

Replace the bush if the measured value is beyond the specified limit.

● **Run-out**

Support the camshaft on two V blocks and check for run-out using a dial indicator. Correct or replace the cam shaft if the amount of run-out is beyond the value indicating need for servicing.

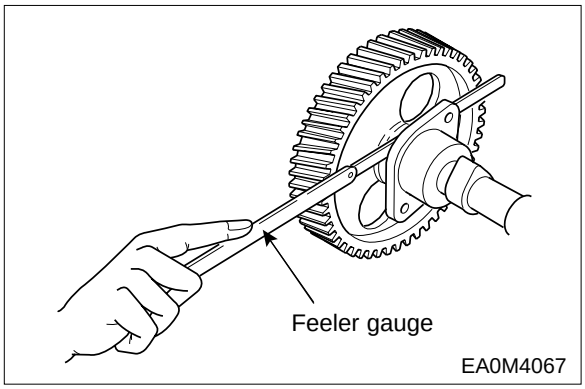
Standard	Limit
0.05 mm	0.2 mm



3) Camshaft end play

- Push the thrust plate toward the cam gear.
- With a feeler gauge, measure the clearance between the thrust plate and camshaft journal.
- If the end play is excessive, replace the thrust plate.

Standard	Limit
0.28 ~ 0.43 mm	0.6 mm



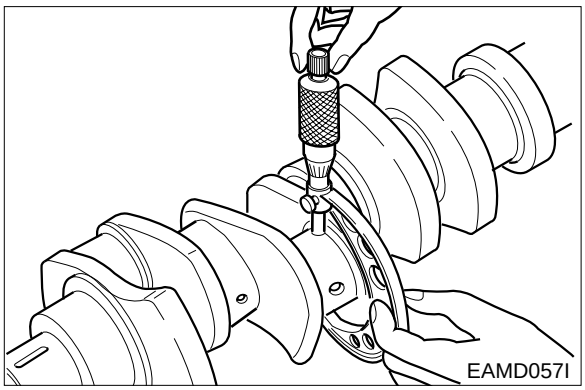
6.2.6. Crank shaft

1) Defect check

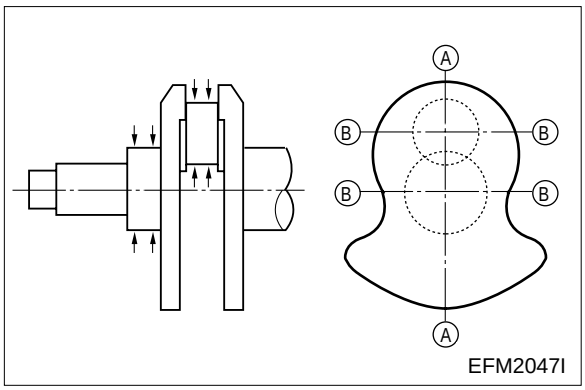
- Visually check the crankshaft journal and crank pins for scores or cracks.
- Using a magnetic power and color check, inspect the crankshaft for cracks, and replace the crankshaft which has cracks.

2) Wear measuring

- With an outside micrometer measure the diameter of the crankshaft journals and pins in the directions as shown, and compare the measured values to determine the amount of wear.
- If the amount of wear is beyond the limit, polish the crankshaft and install undersize bearings. However, if the amount of wear is within the limit, you can correct the wear using an oil stone or oiled grinding paper of fine grain size. (Be sure to use grinding paper which has been immersed in oil.)



	Standard	Limit
Journal diameter	83.966 ~ 83.988	83.000 mm
Pin diameter	70.971 ~ 70.990	70.000 mm



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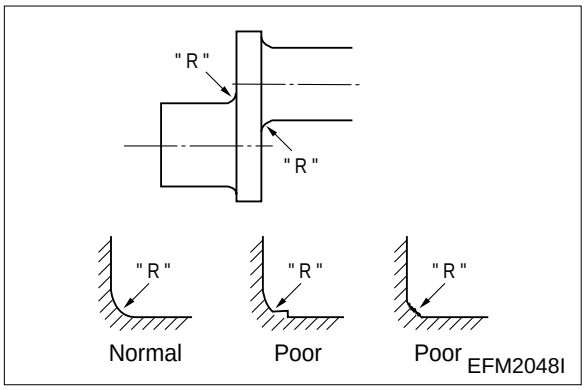
*** Undersize bearings available**

- ♦ Standard
- ♦ 0.25 (Inside diameter is 0.25 mm lesser than the standard size.)
- ♦ 0.50 (Inside diameter is 0.50 mm lesser than the standard size.)
- ♦ 0.75 (Inside diameter is 0.75 mm lesser than the standard size.)
- ♦ 1.00 (Inside diameter is 1.00 mm lesser than the standard size.)

Undersize bearings are available in 4 different sizes as indicated above, and the crankshaft can be reground to the above sizes.

Note : *When regrinding the crankshaft as described above, the fillet section 'R' should be finished correctly. Avoid sharp corners or insufficient fillet.*



EFM2048I

* Standard values of 'R'

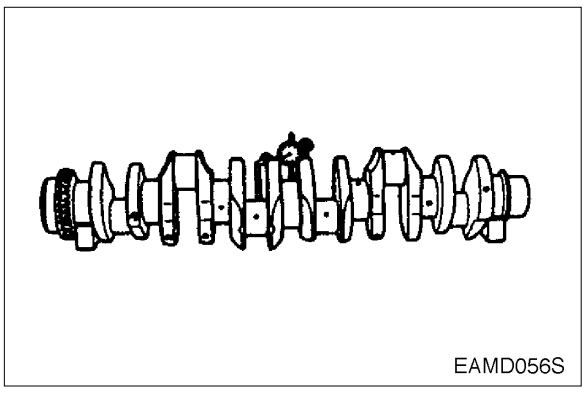
① Crank Pin 'R' : $4.5\ ^{0}_{-0.2}$

② Crank journal 'R' : $4\ ^{0}_{-0.2}$

3) Crankshaft run-out

- Support the crankshaft on V blocks.
- Turn the crankshaft with a dial indicator placed on the surface plate and measure the amount of crankshaft run-out.

Standard	Limit
0.05 mm	0.1 mm


EAMD056S

6.2.7. Crankshaft bearing and con- rod bearing

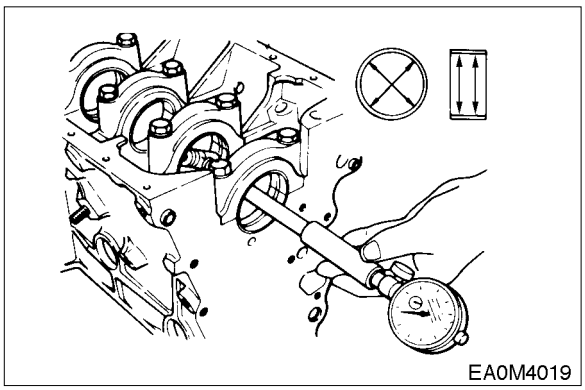
1) Visual check

Visually check the crankshaft bearing and the connecting rod bearing for scores, uneven wear or damage.

2) Oil clearance between crankshaft and bearing.

● **Main bearing clearance**

Install the main bearing in the cylinder block, tighten the bearing cap to specified torque, then measure the inside diameter.



Torque	30 kg·m

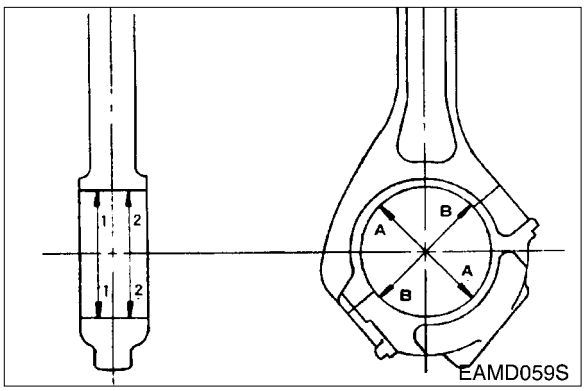
Crank journal Diameter	83.966~83.988 mm

Compare the two values obtained through measurement of the main bearing inside diameter with the outside diameter of the crankshaft journal to determine the oil clearance.

Standard	Limit
0.052 ~ 0.122 mm	0.25 mm

● **Connecting rod bearing clearance (Method 1)**

Install the connecting rod bearing in the connecting rod bearing cap, tighten the connecting rod cap bolts to the specified torque, then measure the inside diameter.

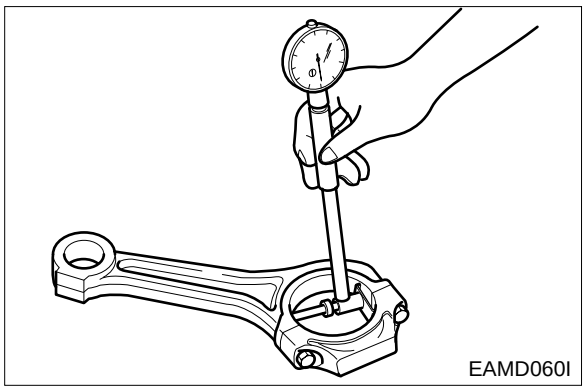


Torque	18 kg·m

Cranck pin Dia.	70.971 ~ 70.990 mm

Compare the two values obtained through measurement of connecting rod bearing inside diameter with the outside diameters of the crankshaft pins to determine the oil clearance.

Standard	Limit
0.049 ~ 0.119 mm	0.20 mm


EAMD060I

If the clearance deviates from the specified range, polish the crankshaft journals and pins ground and install undersized bearings.

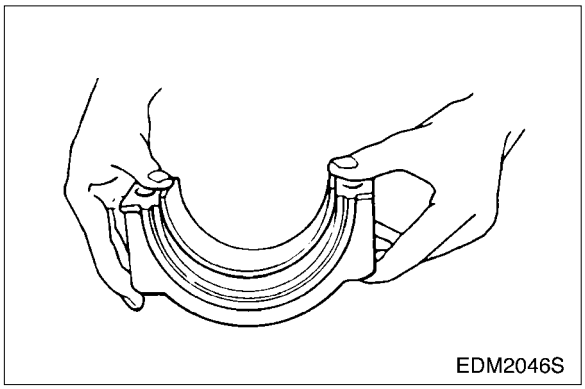
● **Connecting rod bearing clearance (Method 2 : with plastic gauge)**

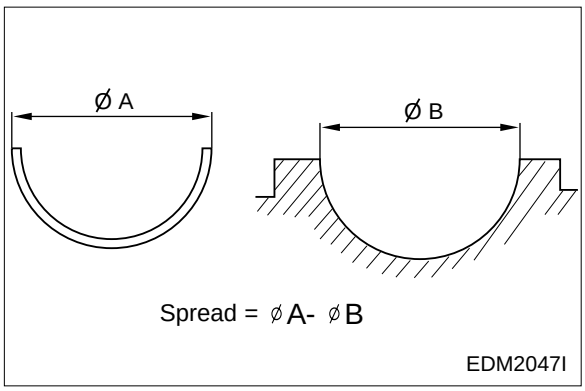
Assemble the crankshaft on the cylinder block and put the plastic gauge on the journal and pin of crankshaft and then after assembling bearing cap, tighten the bolts at the specific torque. Again after disassembling the bearing cap by removing the bolts, take out the flatted plastic gauge and measure the width of plastic gauge by means of plastic gauge measuring scale. This is the oil clearance.

3) Bearing spread and crush

● **Inspection**

Check to see that the bearing requires a considerable amount of finger pressure at re-assembly operation.


EDM2046S



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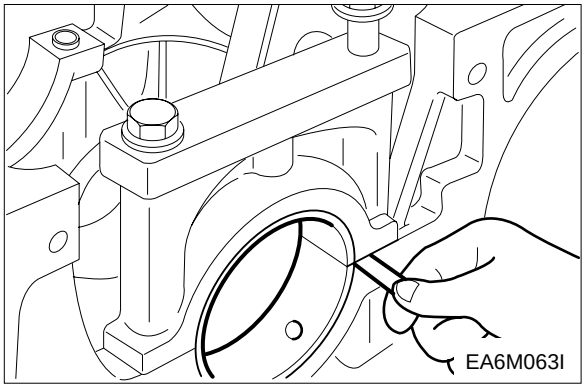
● **Crankshaft bearing crush**

Install the bearing and cap in the cylinder block, retighten the bolts to specified torque, only unscrew out one bolt completely, then measure the clearance between the bearing cap and cylinder block using a feeler gauge.

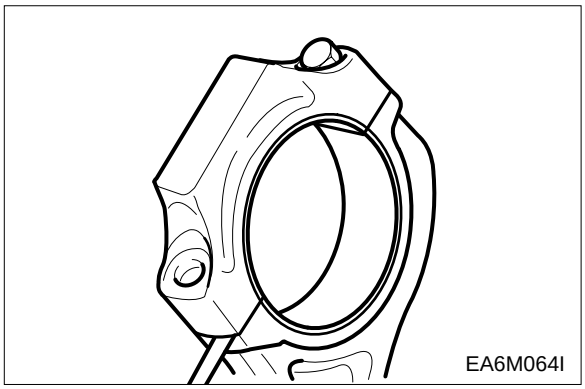
Standard	0.19 ~ 0.22 mm



● **Connecting rod bearing crush**

Install the bearing and cap in the connecting rod big end, retighten the bolts to specified torque, only unscrew out one bolt completely, then measure the clearance between the bearing cap and the connecting rod big end using a feeler gauge.

Standard	0.3 ~ 0.5 mm

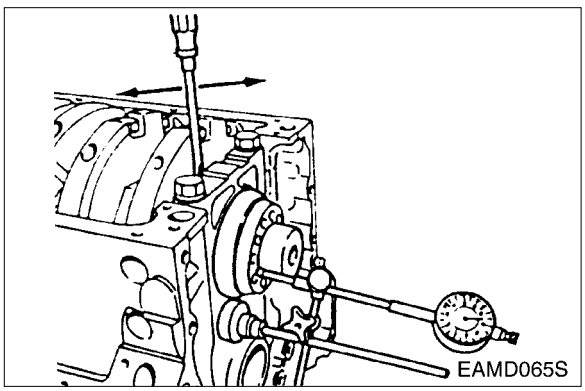


4) Crank shaft end play

● Assemble the crankshaft to the cylinder block.

● With a dial gauge, measure crankshaft end play.

Standard	Limit
0.15 ~ 0.325 mm	0.5 mm



6.2.8. Piston

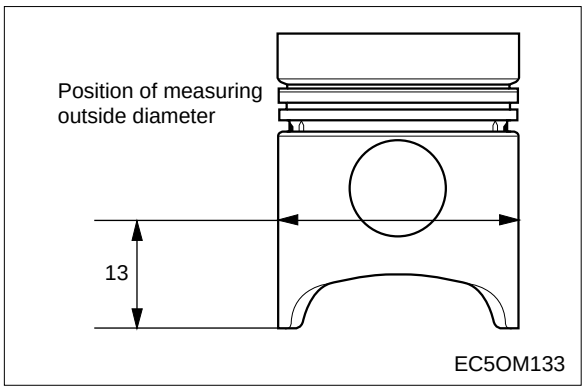
1) Visual check

Visually check the pistons for cracks, scuff or wear, paying particular attention to the ring groove.

2) Clearance between the piston and cylinder liner

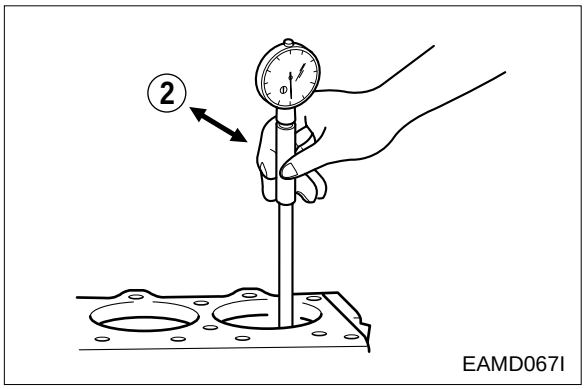
- With an outside micrometer, measure the piston outside diameter at a point 13mm away from the lower end of piston skirt at right angle against direction of the piston pin hole.

Standard	∅110.801 ~ ∅110.959 mm



- Using a cylinder bore gauge, measure cylinder liner inside diameter at 3 points (Contacting face of the cylinder 1st, 2nd, and oil rings on B.D.C) in a direction at an angle of 45° separately. Take the mean value except the largest and smallest values.

Standard	Limit
111 ~ 111.022 mm	111.222 mm



- The clearance is computed by subtracting the piston outside diameter from the cylinder liner inside diameter. Replace either piston or cylinder liner, whichever damaged more, if the clearance is beyond the specified limit.

<Clearance between piston and liner>

Standard	0.041 ~ 0.221mm

6.2.9. Piston rings

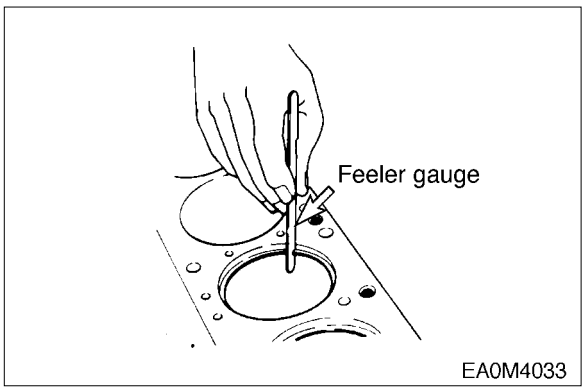
1) Visual check

Replace the piston rings with new ones if detected worn or broken when the engine is overhauled.

2) Piston ring gap

- Insert the piston ring into the upper portion of the cylinder liner bore and then it should be positioned at a right angle against the cylinder liner wall surface.

- Measure the piston ring gap with a feeler gauge.

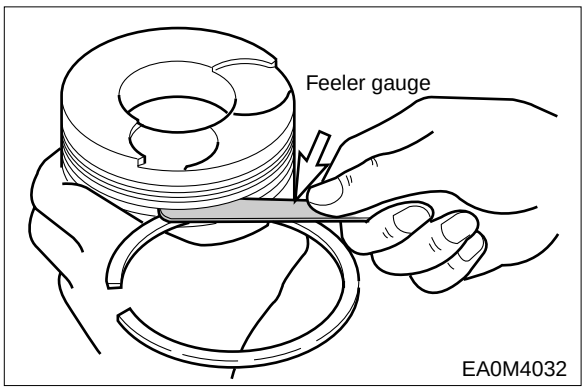


	Standard	Limit
Top ring	0.40 ~ 0.65 mm	1.5 mm
2nd ring	0.40 ~ 0.65 mm	1.5 mm
Oil ring	0.30 ~ 0.60 mm	1.5 mm

Replace piston rings with new ones if the gap is beyond the limit

3) Piston ring side clearance

- Fit the compression rings and oil ring in the piston ring grooves.
- With a feeler gauge, measure side clearance of each ring, and replace either the ring or piston if the measured value is beyond the specified limit.



	Standard	Limit
Top ring	Tapered Type	
2nd ring	0.07 ~ 0.102 mm	0.15 mm
Oil ring	0.05 ~ 0.085 mm	0.15 mm

4) Piston ring tension

With a tension tester, measure piston ring tension. Replace the piston ring if the measured value is beyond the limit.

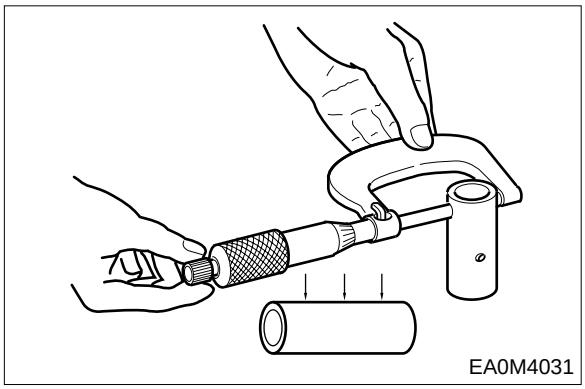
	Standard
Top ring	2.58 ~ 3.88 kg
2nd ring	1.81 ~ 2.71 kg
Oil ring	3.57 ~ 5.03 kg

6.2.10. Piston pin

1) Wear

Measure the amount of wear on the piston pin at the points as shown. If the measured values are beyond the limit (0.005 mm or greater), replace the pin.

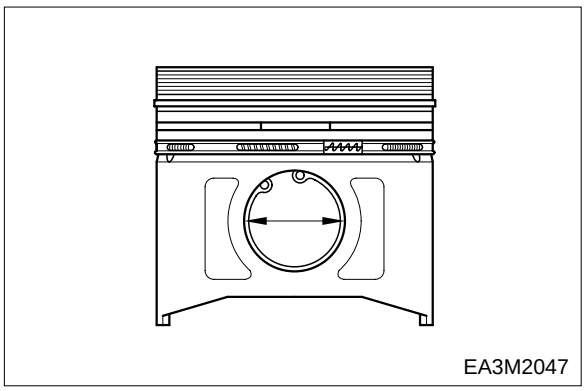
Standard	Limit
41.944 ~ 42.000 mm	41.940 mm or less


EA0M4031

2) Clearance

Measure the clearance between the piston pin and connecting rod bush, and replace either of them, whichever damaged more, if the measured value is beyond the limit.

Standard	Limit
0.009 ~ 0.015 mm	0.08 mm


EA3M2047

3) Condition check

Check the insertion condition of the piston and piston pin. If it is possible to force the pin into the piston heated by piston heater, the piston is normal.

When replacing the piston, be sure to replace the piston pin together.

6.2.11. Connecting rod

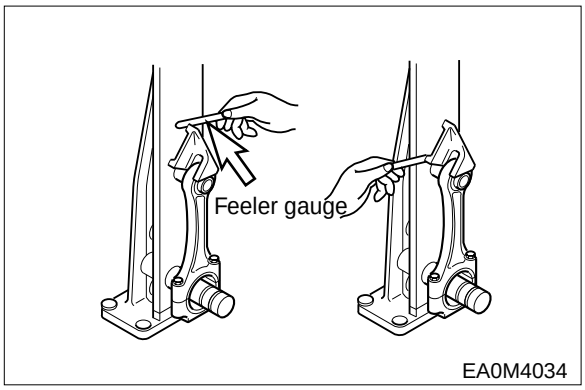
1) Distortion

Check the connecting rod for distortion. As shown in the figure below, install the connecting rod to the connecting rod tester, and check for distortion using a feeler gauge. If the connecting rod is found distorted, never re-use it but replace with a new one.

2) Holes alignment (parallelism)

Measure the alignment of the connecting rod small bushing hole and the connecting rod big end hole. At this time also, use both connecting rod tester and feeler gauge.

Standard	Limit
0.05 mm	0.1 mm or less



3) Wear

- Assemble the connecting rod to the crankshaft and measure connecting rod big end side clearance using a feeler gauge.
- Assemble the connecting rod to the piston and measure connecting rod small end side clearance.
- If the measured values are beyond the limit, replace the connecting rod.

Limit	0.5 mm

6.3. Engine Re-assembly

6.3.1. General precautions

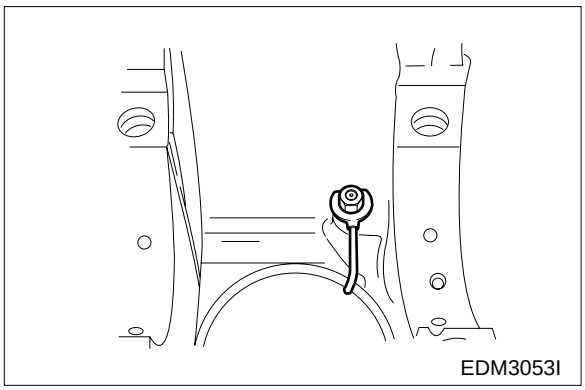
- Clean all the disassembled parts, particularly oil and water ports, using compressed air, then check that they are free from restrictions.I
- Arrange the general and special tools in order to engine assembly operation.
- To lubricate each sliding part, prepare the clean engine oil.
- Prepare maintenance materials such as sealant, gaskets, and etc.
- Discard used gaskets, seal rings, and consumable parts, and replace with new ones.
- Apply only the specified torque for bolts in the specified tightening order and avoid over-tightening.
- Be sure to check that all the engine parts operate smoothly after being reassembled.
- Check the bolts for looseness after preliminary re-assembly.
- After completing the engine re-assembly operation, check if there is missing parts or shortage of parts.
- Keep your hands clean during the maintenance.

6.3.2. Cylinder block

- Cover the floor of the workshop with wood plate or thick paper to prevent damage to the cylinder head and place the head face of the cylinder block towards downward.

6.3.3. Oil spray nozzle

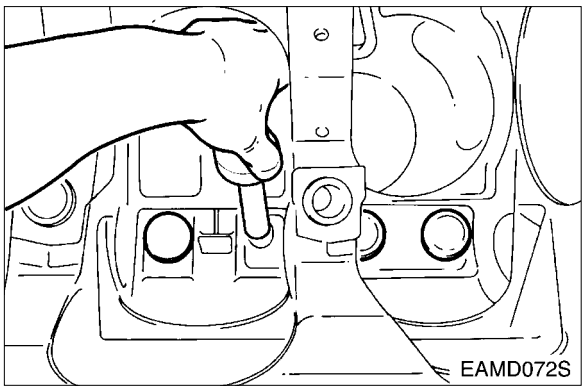
- Tighten and assemble the oil spray nozzle with fixing bolts using the spray nozzle jig.



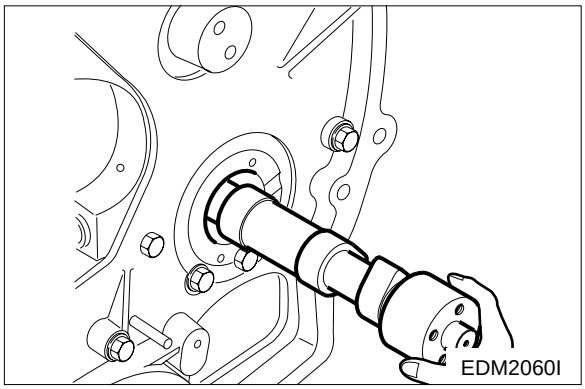
6.3.4. Tappet and cam shaft

- Under cool a new bush with dry ice for about 2 hours and press it into position in the cylinder block using a bench press. After the pressing operation, measure the inside diameter of the cam bush to check if it is not deformed.

- Apply engine oil to the entire face of the tappets and slide them into the tappet holes on the cylinder block.

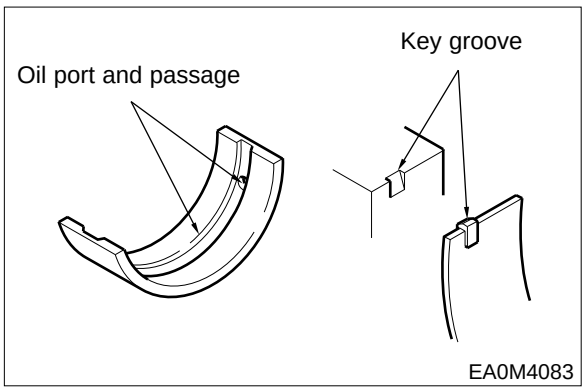


- Wet the cam bush inside diameter and camshaft with oil, and carefully assemble them while turning the camshaft.
- Check to see that the camshaft rotates smoothly.

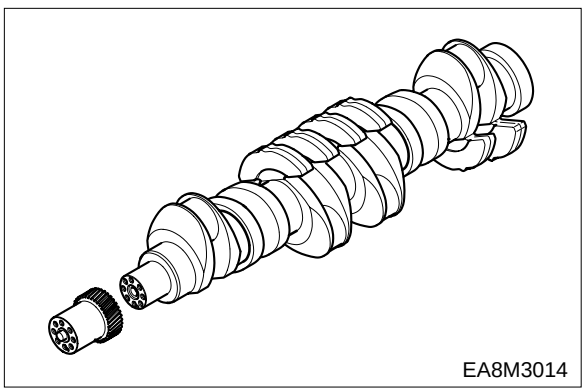


6.3.5. Crankshaft

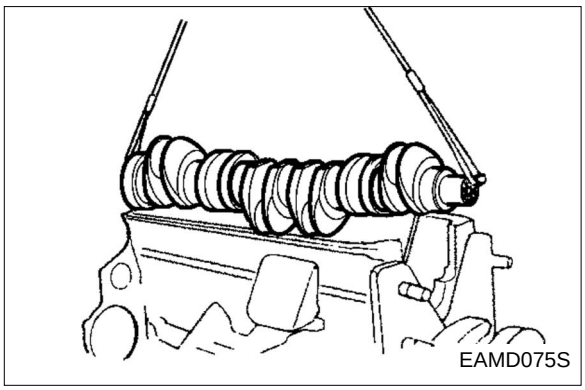
- Install the main bearing machined with two holes in the cylinder block so that the key is aligned with the key groove, then apply oil to the bearing surface.



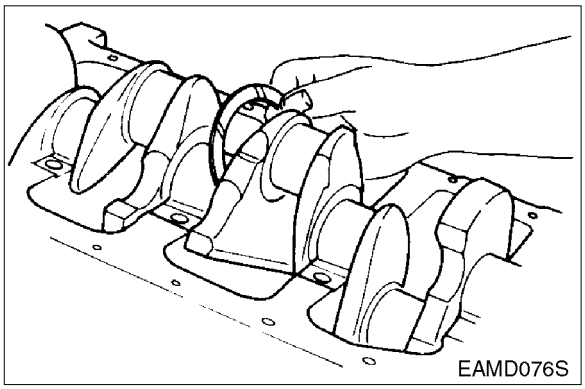
- Heat the crankshaft gear for at least 10 minutes to 120° C then apply sealant (Loctite # 641) to the inside wall of the heated crankshaft gear evenly before inserting it to the end of crankshaft.



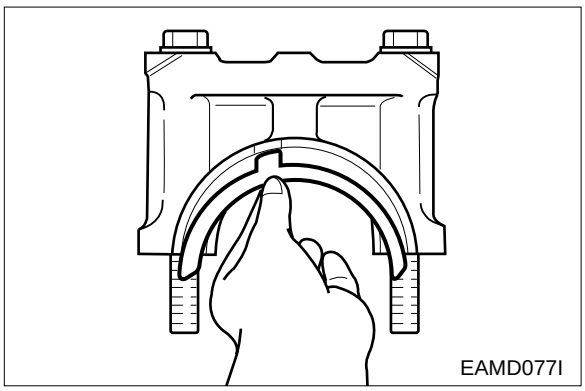
- Semi-tighten a bolt at both sides of the crankshaft, apply engine oil to journals and pins, then assemble the crankshaft with the cylinder block by tightening the fixing bolts.


EAMD075S

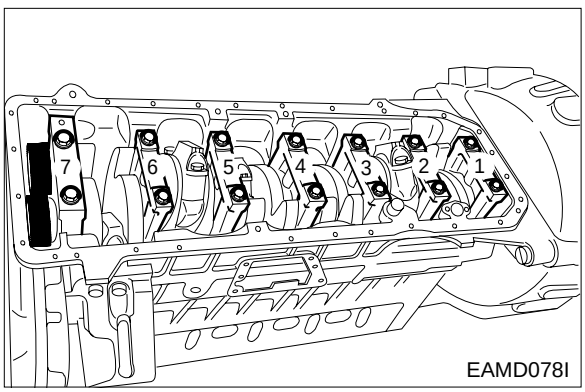
- Install the oiled thrust washers with the oil groove facing outward of the bearing.


EAMD076S

- Install the bearing and thrust washers to the bearing cap and apply oil to the bearing and thrust washers.


EAMD077I

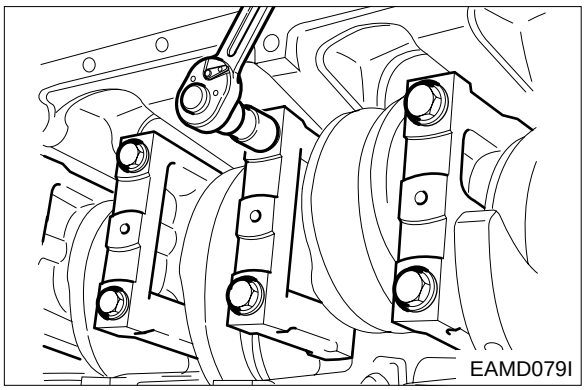
- Install the bearing cap by matching the cylinder block number compare with the bearing cap number.



EAMD078I

- Apply oil to the entire part of the bearing cap bolts, then tighten in tightening sequence to specified torque.

Torque	30 kg·m


EAMD079I

- After semi-tightening both bolts evenly, tighten them diagonally specified torque using a torque wrench as follows.

<Tightening order>

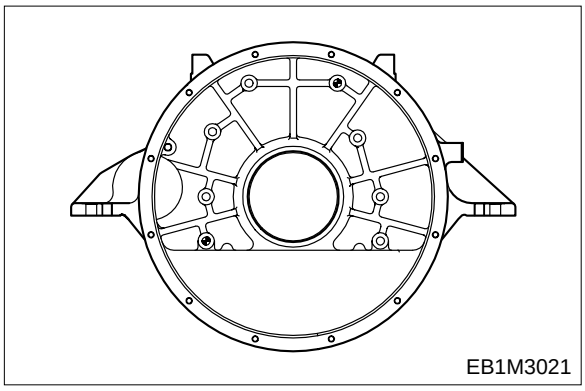
(1) First stage : Coat engine oil over the bolts.
(2) Second stage : Temporary assemble the bolts about 1 ~ 2 threads
(3) Third stage : With impact wrench, tighten up to about 15 kg·m
(4) Fourth stage : With torque wrench, tighten up to about 25 kg·m
(5) Fifth stage : By means of torque wrench, tighten finally in the specified torque. (30 kg·m).

- Tighten the bearing cap in the sequence of its number 4-3-5-2-6-1-7.
- Check to see that the assembled crankshaft turns smoothly.

6.3.6. Flywheel housing

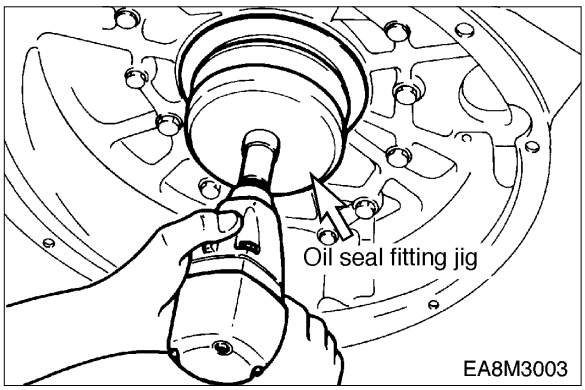
- Temporarily install the guide bar on the cylinder block.
- Apply gasket to the cylinder block.
- Using the dowel pin and guide bar, install the flywheel housing and tighten the fixing bolts in a diagonal sequence to specified torque.

Torque	8 kg·m


EB1M3021

6.3.7. Rear oil seal

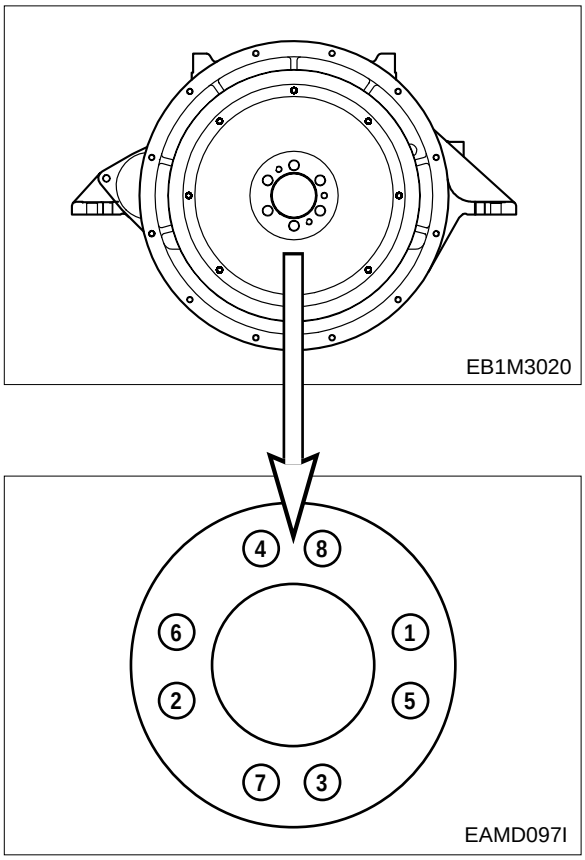
- Apply lubricating oil to the outside of the oil seal and flywheel housing inside diameter and fit them over the crank shaft, then assemble the oil seal using an oil seal fitting jig.



6.3.8. Flywheel

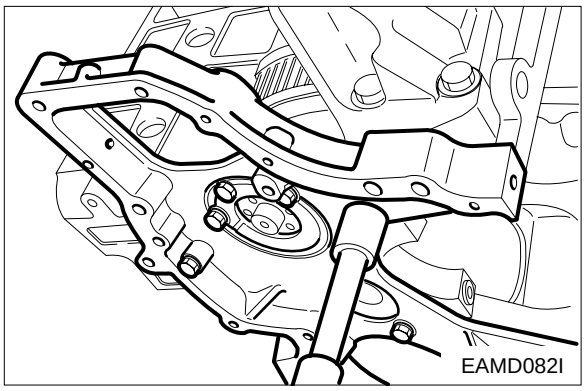
- Install a guide bar into a bolt hole on the crank shaft, and lift the flywheel to align the dowel pin with the pin hole on the flywheel for temporary assembly operation.
- Install bolts in the remaining holes, take out the guide bar, then install a bolt in the hole where the guide bar had been inserted.
- Tighten the fixing bolts using a torque wrench in a diagonal sequence to specified torque.

Torque	21.5 kg·m



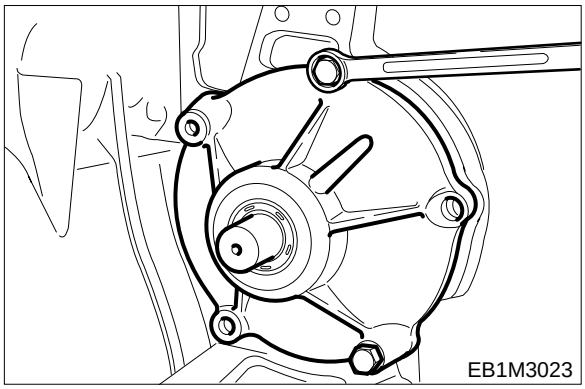
6.3.9. Timing gear case

- Mount the gasket using dowel pin on the cylinder block.
- Install the timing gear case by aligning the dowel pin with the dowel pin hole on the timing gear case.



6.3.10. Injection pump drive gear

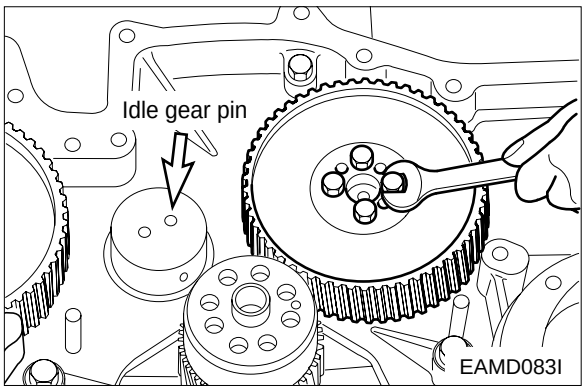
- Mount the gasket by aligning the bolt holes with the pin holes on the bearing housing.
- Tighten up the fixing bolts in the direction of fuel injection pump.



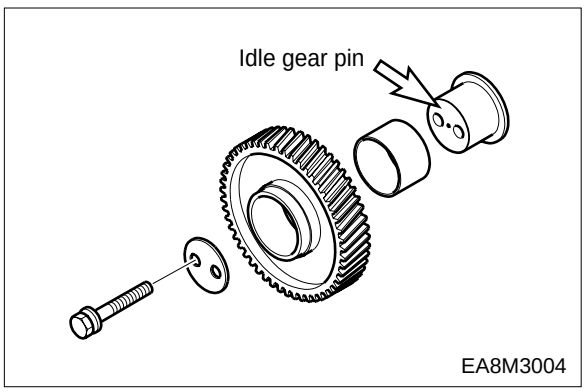
6.3.11. Timing gear

- Install the oil pump idle gear into the No.7 bearing cap.
- Install a thrust washer over the camshaft and assemble the cam gear by aligning it with camshaft key groove.

Torque	2.2 kg·m

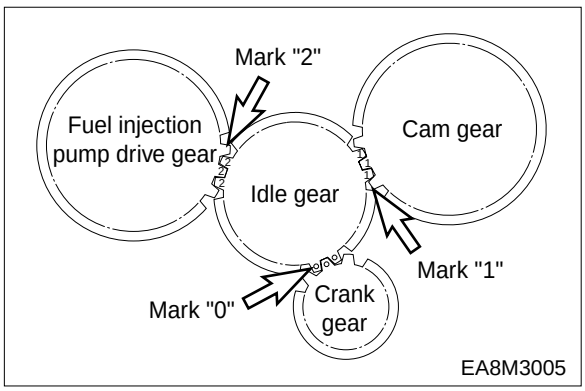


- After the oil port on the idle gear pin towards the cylinder block, install the idle gear pin.



- Install the idle gear by coinciding the marks impressed on the crank gear, cam gear, fuel injection pump drive gear, and idle gear each other.
- Install a thrust washer on the idle gear and tighten to specified torque.

Torque	6.2 kg·m

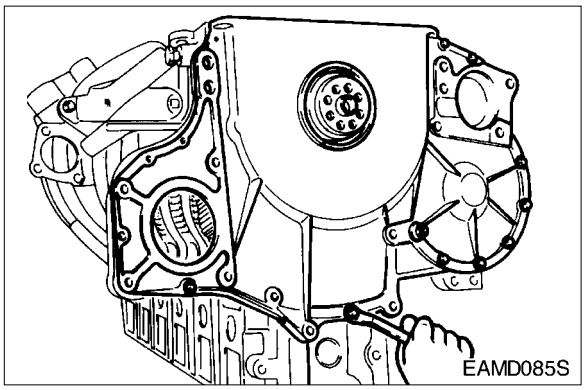


- Check and adjust the amount of backlash between gears using a feeler gauge.

Items	Standard	Limit
Cam gear & idle gear	0.16 ~ 0.28 mm	0.35 mm
Crank gear & idle gear	0.16 ~ 0.28 mm	0.35 mm
Injection pump & idle gear	0.16 ~ 0.28 mm	0.35 mm

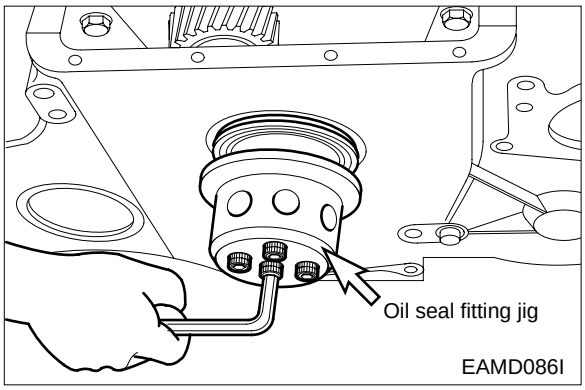
6.3.12. Timing gear case cover

- Install the dowel pin on the timing gear case.
- Mount a gasket by aligning the fixing bolt holes with those on the gasket.
- Align the dowel pin with the cover pin hole, then install the cover with light tap.
- Tighten the fixing bolts beginning with the oil pan fitting face.



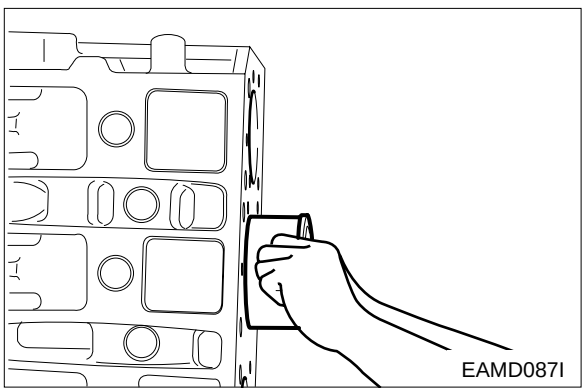
6.3.13. Front oil seal

- Apply lubricating oil to the outside of the oil seal and timing gear case inside diameter and fit it over the crankshaft, then assemble the oil seal using an oil seal fitting jig.



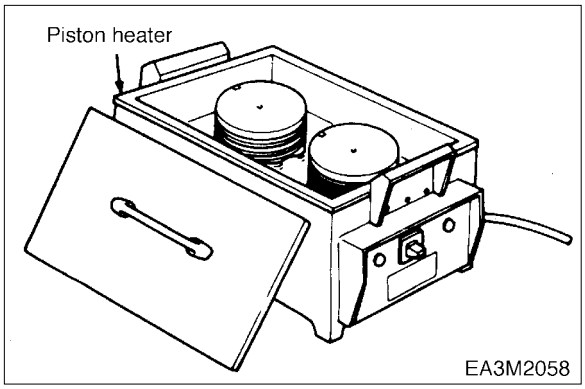
6.3.14. Cylinder liner

- Stand the cylinder block so that the flywheel faces downward.
- Thoroughly clean the liner flange fitting surface and bore inside with compressed air to prevent the entry of foreign substances.
- After the cleaning operation, make the cylinder liner dried up and push it into the cylinder block by hand.
- Wet the liner inside diameter with engine oil.

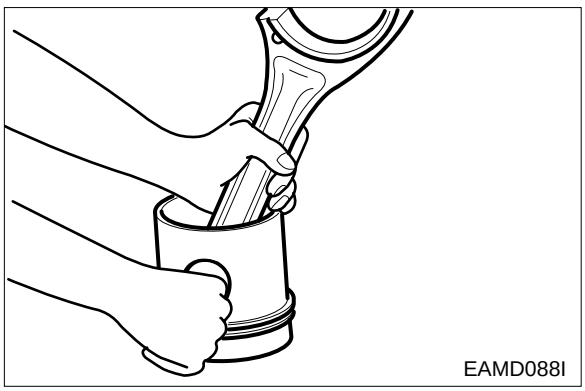


6.3.15. Piston and connecting rod

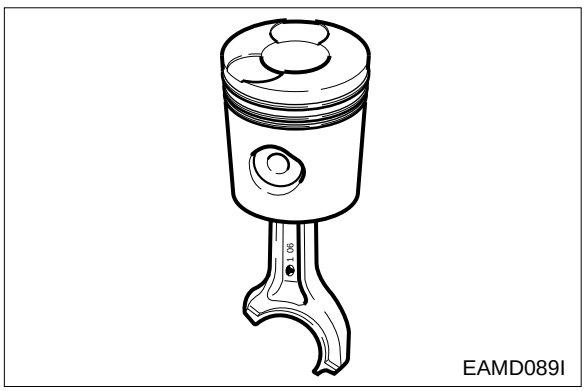
- Use a piston heater to heat the piston approximately 100 °C ~ 212 °F for 5 minutes.



- Align the piston pin hole with the connecting rod small end bush oiled and press the piston pin (by lightly tapping with a rubber hammer) to assemble the connecting rod into the piston.



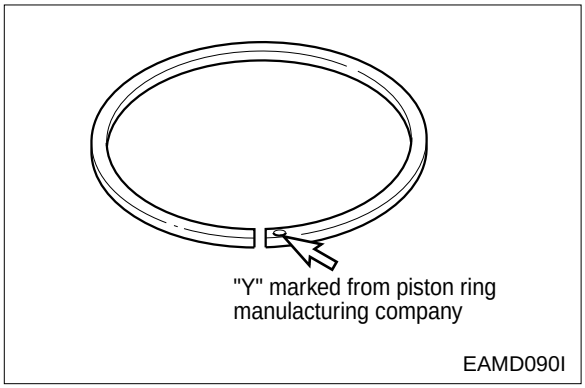
- Noticing the direction of the piston, make the longer side (machined with key groove on the bearing) of the connecting rod big end and the mark of ' ' impressed on the inside of the piston face each other in opposite directions. On the piston head surface, the longer side of the connecting rod big end is in opposite direction from the valve seat surface.



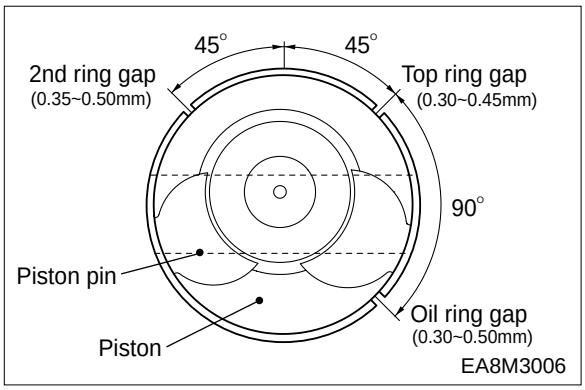
- Install the snap rings and check to see that it is securely assembled.
- Install the piston ring in the piston using piston ring pliers.

- Identify the mark “Y” on the piston ring end to prevent assembling the bottom of the piston ring is being interchanged with its top faced marked “Y”.

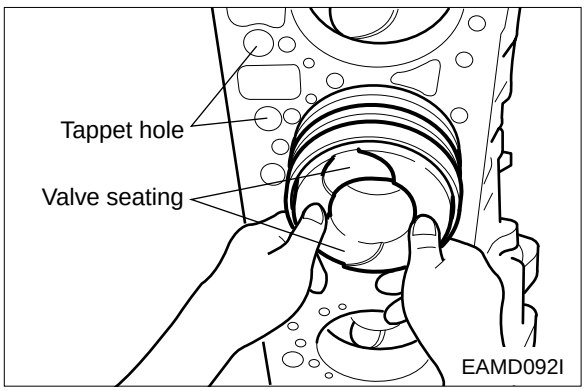
Note : *Be sure to make the piston ring end marked face(“Y”) upward.*



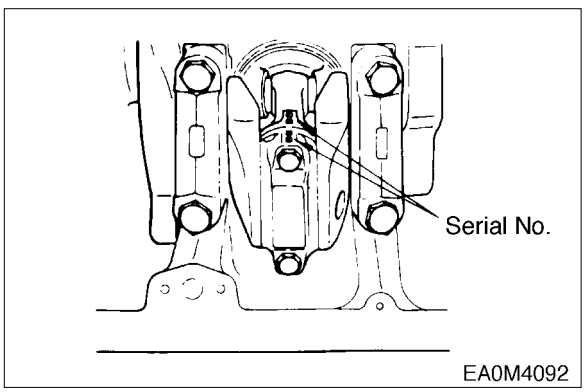
- Adjust the angle among individual piston ring gaps to 90° and fit a piston assembling jig onto the piston, Use care not to match the ring gaps with the piston pin direction.
- Install the bearing by aligning it with the connecting rod key groove and apply oil to the bearing and piston.



- Make a position the valve seating surface toward the tappet hole and insert the piston with hand.
  Use care not to damage the cylinder liner and piston, and slightly lift and insert the piston into the cylinder so that the ring may not be damaged by the fillet of the liner.
- Install the bearing in the connecting rod cap and apply oil.



- Make sure that the manufacture serial number impressed on the connecting rod cap and the connecting rod big end is identical, and install the connecting rod cap by aligning it with dowel pin.
- Wet the fixing bolts with oil, semi-tighten them by hand, tighten them to specified torque using a torque wrench as follows.

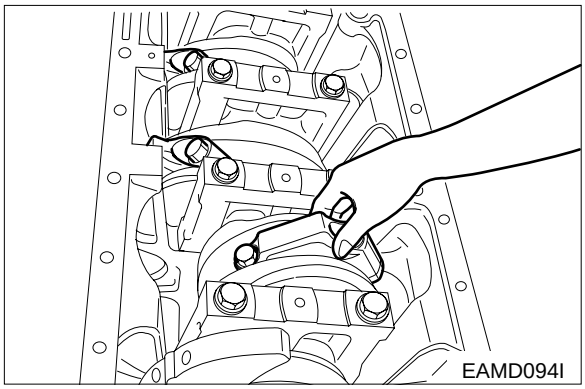


<Tightening order>

(1) First stage : Coat engine oil over bolts
(2) Second stage : Temporary screw the bolt about 1 ~ 2 threads
(3) Third stage : With torque wrench, tighten at about 10 kg·m
(4) Fourth stage : With torque wrench, tighten up to about 15 kg·m
(5) Fifth stage : Finally, tighten in the specified torque 18kg·m with torque wrench .

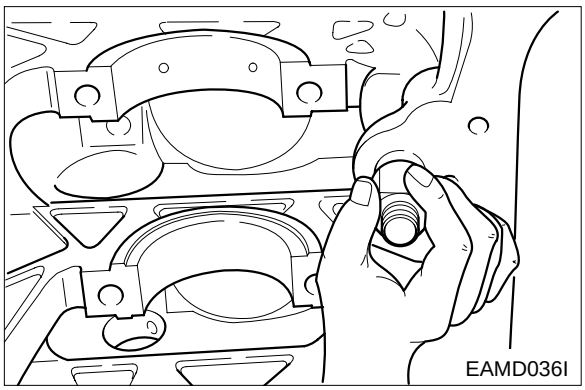
Torque	18 kg·m

- Move the bearing cap with hand, and release and reassemble it if no movement is detected.



6.3.16. Relief valve

- Assemble the relief valve.

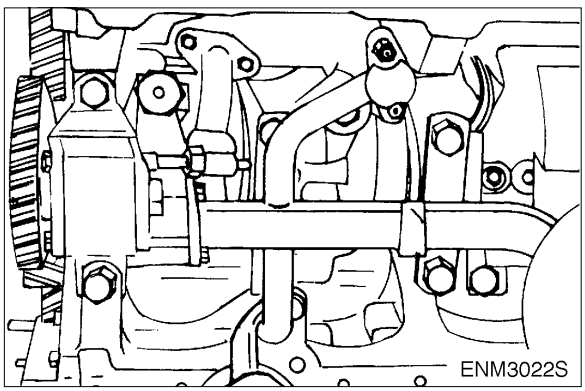


6.3.17. Oil pump and oil pipe

- Install a dowel pin in the No.7 bearing cap, then assemble the oil pump with specified torque.

Torque	4.4 kg·m

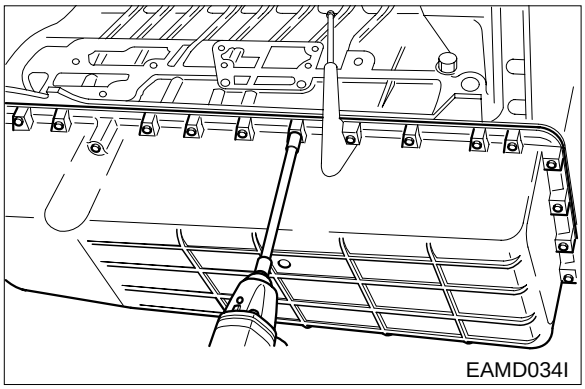
- Assemble the oil suction pipe with the delivery pipe, then install the bracket on the bearing cap.



6.3.18. Oil pan

- Mount gasket and put the oil pan thereon.
- Align the bolt holes with gasket holes to prevent damage to the gasket and tighten bolts to specified torque.

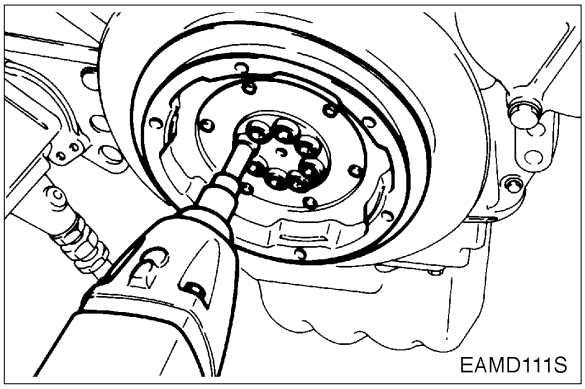
Torque	2.2 kg·m



6.3.19. Vibration damper and pulley

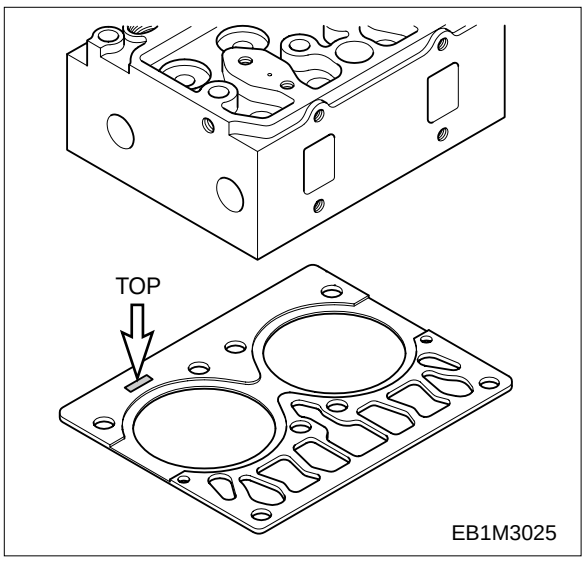
- Assemble the vibration damper on the Crankshaft pulley.
- Install the crankshaft pulley assembly on the crankshaft, then tighten the bolts and thrust washers.

Torque	13.4 kg·m

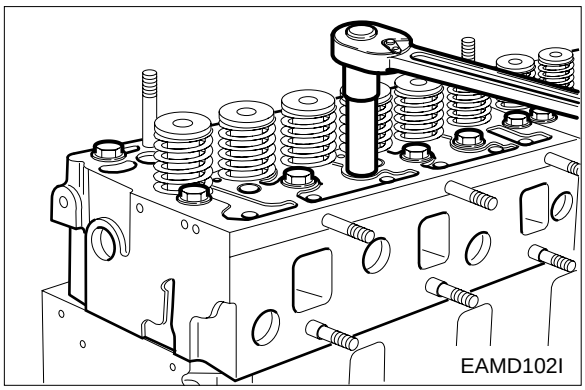


6.3.20. Cylinder head

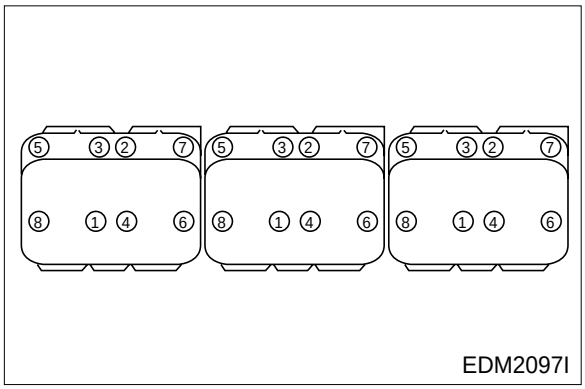
- Install the injection nozzle fixing stud bolts and water pipe fixing stud bolts.
- Clean the head bolt holes on the cylinder block with compressed air to remove foreign substances and thoroughly clean the gasket fitting face of the cylinder block.
- Install head gasket, with 'TOP' mark facing upward, on the cylinder block by aligning the holes with dowel pins.



- Check the inside of combustion chamber for foreign substances, and carefully mount the cylinder head on the cylinder block by aligning the dowel pin in the pin hole. Be careful not to damage the head gasket. If the dowel pin is not in alignment, lift the cylinder head again and then remount it.


EAMD102I

- Coat the head bolts with engine oil, then tighten them in proper sequence to the specified torque according to bolt tightening order. (refer to the figure)



EDM2097I

<Cylinder Head Bolts>

	Type 1	Type 2
Specification	TY 12.9T M14X1.5X146	TY 10.9T M14X1.5X146
Torque	24.5 kg·m	6 kg.m +180˚+150˚

However, before tightening bolts, align the side face of 3 cylinder heads with parallel. They should be adjusted in a straight line exactly.

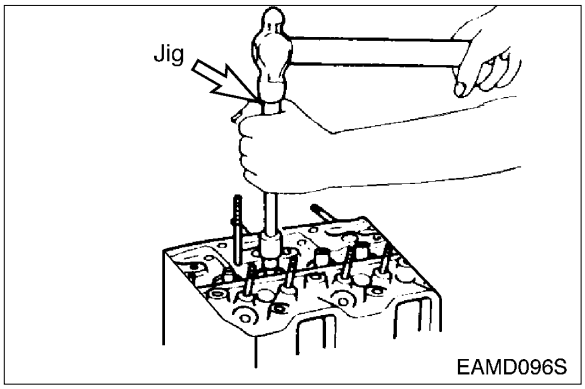
<Tightening order of bolts by steps>
(1) First stage : Coat the bolts with engine oil.
(2) Second stage : Tighten 1 ~ 2 threads with hands.
(3) Third stage : Tighten at about 6 kg.m with a wrench.
(4) Fourth stage : Tighten at rotating angle method 180° with a wrench.
(5) Fifth stage : Finally, tighten at rotating angle method 150° with a torque wrench .

However, all bolts are tightened simultaneously by above steps as possible.

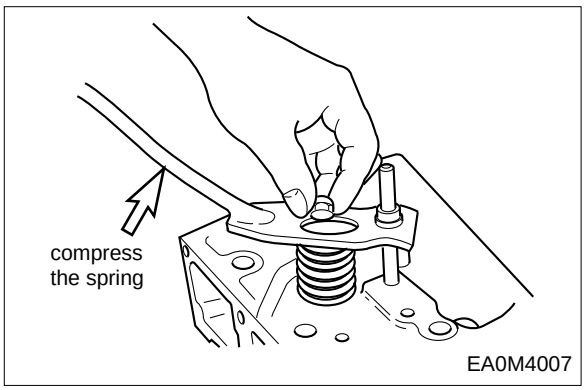
- Coat the push rod with engine oil and insert it into the push rod hole.

6.3.21. Intake and exhaust valves

- Identify the marks of “IN” and “EX” impressed on the valve head before assembling the valve in the head.
- With a valve stem seal fitting jig, assemble the valve guide and stem seal.



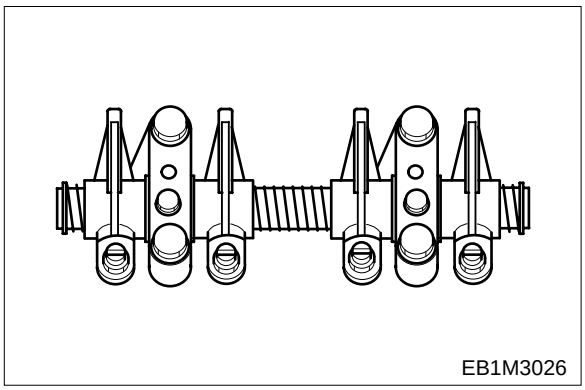
- After installing valve springs and spring retainer, press the retainer with a jig, then install cotter pin.
- Tap the valve stem lightly with a rubber hammer to check that the valve is assembled correctly.



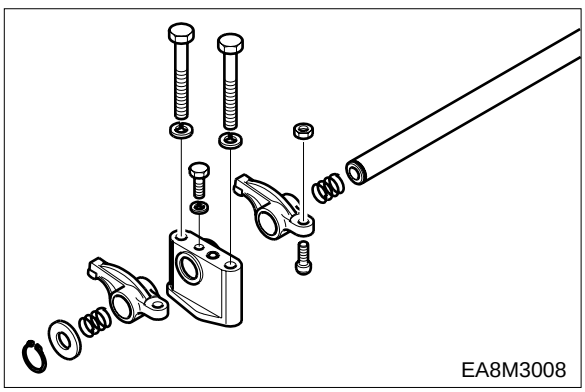
6.3.22. Rocker arm assembly

- Apply lubricating oil to the rocker arm bush and shaft, and assemble the intermediate bracket with the rocker arm using fixing bolts.

Torque	4.4 kg·m

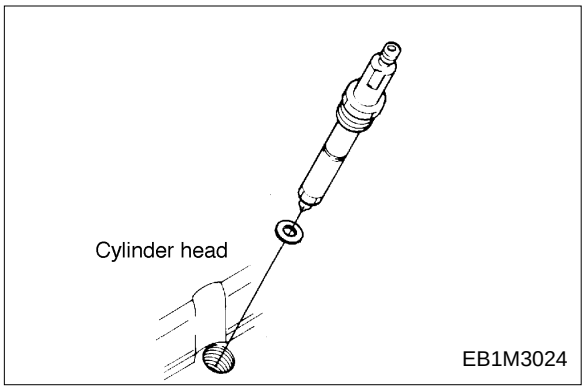


- Semi-install the valve clearance adjusting bolts onto the rocker arm.
- Install the spring, rocker arm, bracket, rocker arm, spring, washer, and snap ring in the described sequence.
- Install the rocker arm and bracket in the same direction.



6.3.23. Injection nozzle

- Install the dust seal with its round portion facing downward.
- Mount a seal ring on its position of the cylinder head and then assemble the nozzle holder.

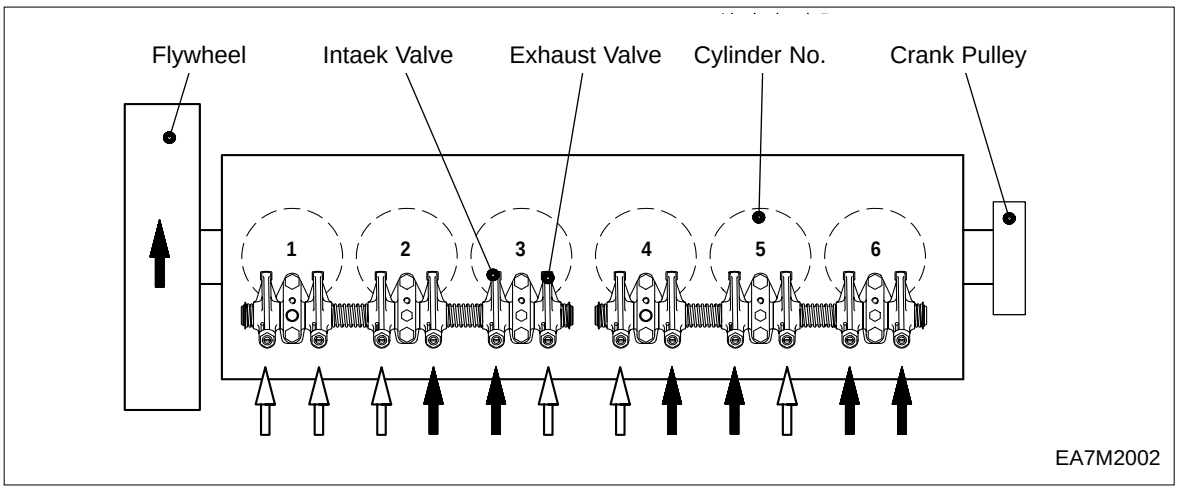


- Be sure to follow the specified torque.

Torque	7.0 kg·m

6.3.24. Valve clearance adjustment

- Cylinder No. 1 begins from the rear side where the flywheel is mounted but cylinder No. 6 begins from the front side of the engine on the contrary.



Step 1 :

- After letting the cylinder No.6 in the overlap TDC position by turning the crankshaft, adjust the valves corresponding to "⇧" of following figure. At this time cylinder No. 1 should be at the ignition TDC position.

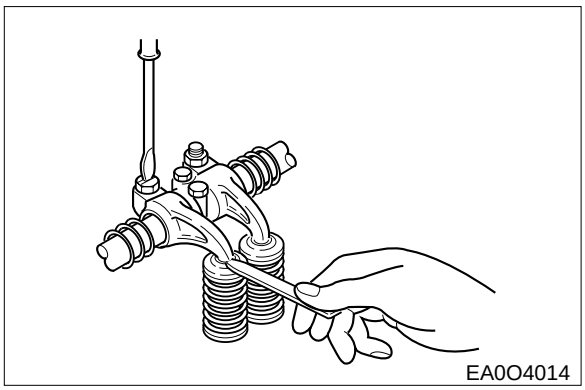
Step 2 :

- After adjusting upper valves turn the crank pulley 360° to adjust the other valve clearance until the cylinder No. 1 comes to overlap TDC position.
  At this time cylinder No. 6 should be at the ignition TDC position(O.T).
- Adjust the valve corresponding to " ⬆ " of upper figure.
  After reconfirming the valve clearances, retighten it if necessary.
- Loosen the lock nuts of the rocker arm adjusting screws and push the specified feeler gauge and adjusting the valve clearance with adjusting screw respectively.

Model	Intake Valve	Exhaust Valve
L136/T/TI/086TI **AD136/T/TI/086TI**	0.3 mm	0.3 mm

- Adjust valve clearance with a feeler gauge and tighten the fixing nuts to specified torque.

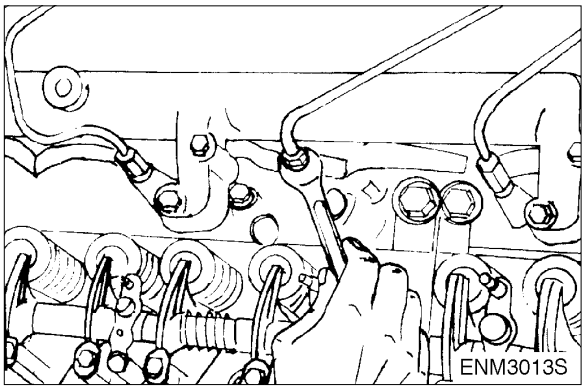
Torque	4.4 kg·m



6.3.25. Injection pipe

- Semi-assemble the nuts at both ends of the fuel injection pipe and tighten them up one by one to specified torque.

Torque	2.9 ~ 3.2 kg·m

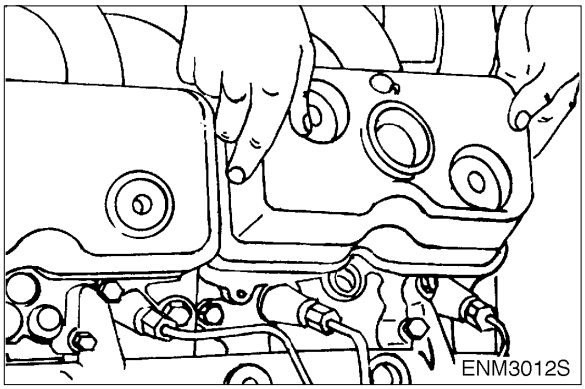


- Tighten the hollow screws to assemble the fuel return pipe.
- Assemble the fuel return hose on the fuel injection pump.

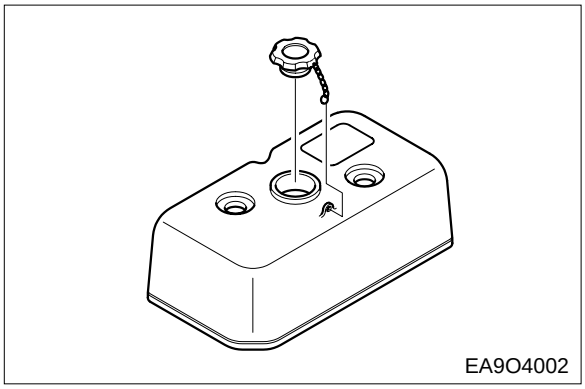
6.3.26. Cylinder head cover

- Assemble the new packing in the cylinder head cover, install the cover on the cylinder head, then tighten the fixing bolts in sequence to specified torque.

Torque	1.5 kg·m



- Assemble the breather hose and the breather assembly.
- Assemble the oil filler cap in the cylinder head cover.



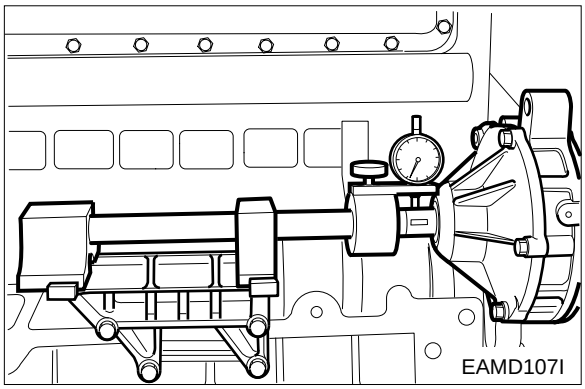
6.3.27. Injection pump & injection timing

(1) Fuel injection pump

(A) L086TI, AD086TI

- Install the injection pump bracket in the cylinder block.
- After measuring the amount of run-out with an alignment setting jig, disassemble the bracket, adjust the shims, then reassemble it.

Run out	0.2 mm or less

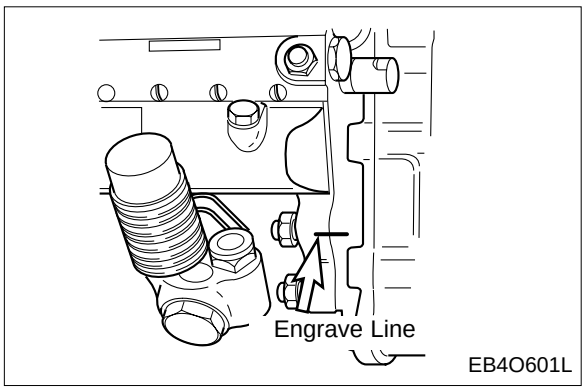


- Mount the top/bottom adjusting shims in the bracket and then mount the fuel injection pump.
- Tighten the fixing bolts in a diagonal sequence to specified torque.

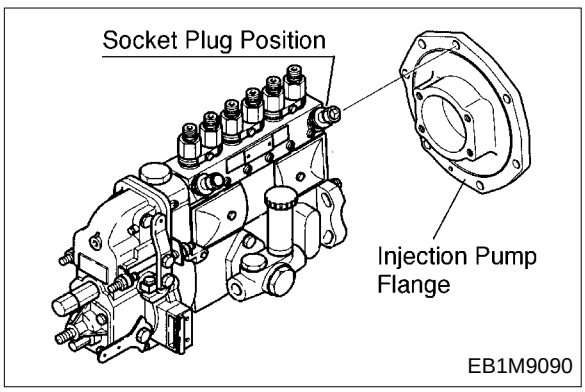
Torque	4.4 kg·m

(B) L136/T/TI, AD136/T/TI

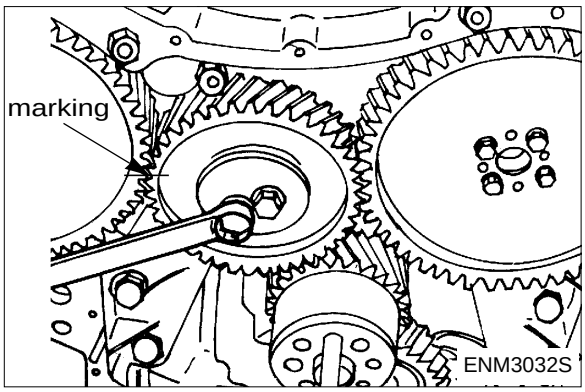
- Reassemble the injection pump by using the engraved line as the figure.



To assemble the new injection pump, align the center of the hexagonal socket plug on the front side of the injection pump with the upper bolt hole of the injection pump flange.



Then assemble the injection pump gear by aligning with the oil paint marking lines as figure.

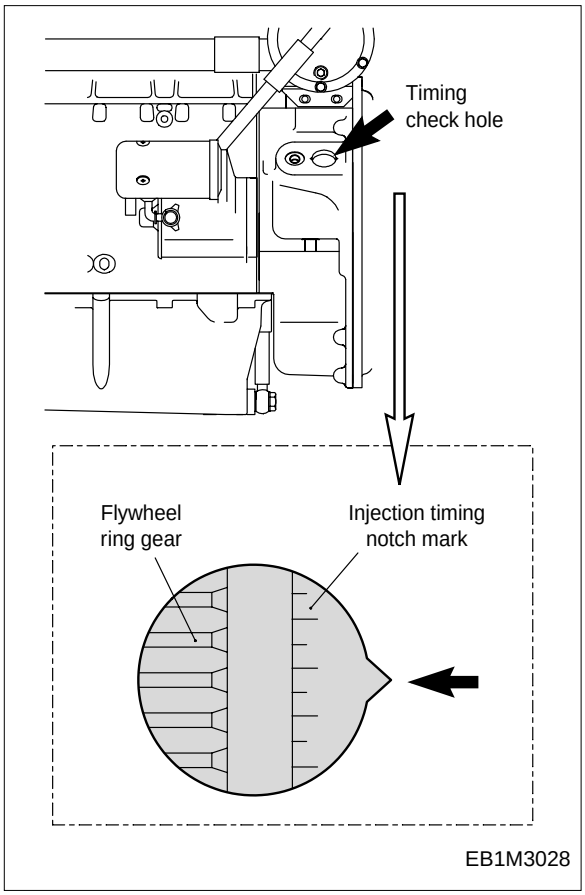


(2) Injection timing

- Turn the crank shaft until cylinder No. 6 is placed in the overlap TDC and then turn again the flywheel clockwise until the notch mark corresponding to the injection timing degree its model is aligned with hole center(⬅) in the flywheel as right figure.

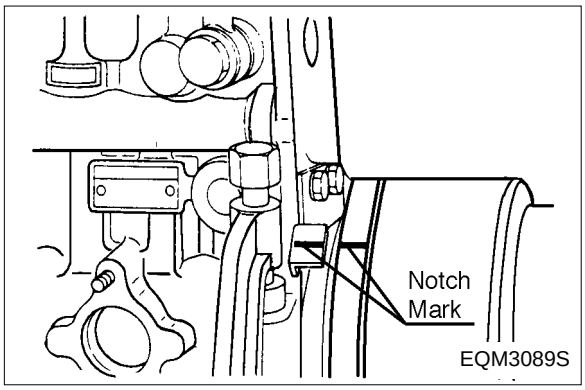
<Fuel injection timing>

Refer to "**1. Engine specification**" for each model.



(A) L086TI, AD086TI

- After letting the cylinder No. 6 at overlap TDC position, adjust the injection timing degree of the engine.
- After that, turn the injection pump until the notch mark of the pump indicator plate mounted is aligned with the notch mark of the drive shaft flange as right figure.

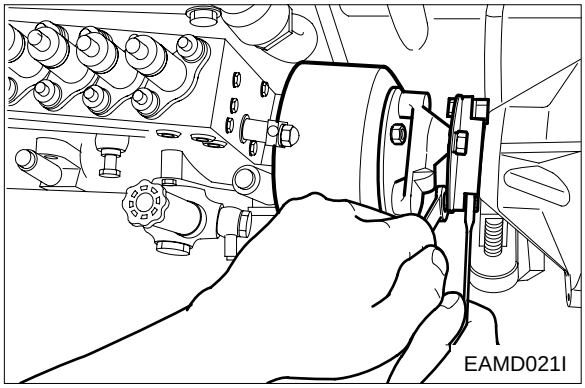


- Tighten the coupling housing fixing bolts and nuts to specified torque.

Torque	6.0 kg·m

- Tighten the coupling housing fixing bolts and nuts to specified torque.

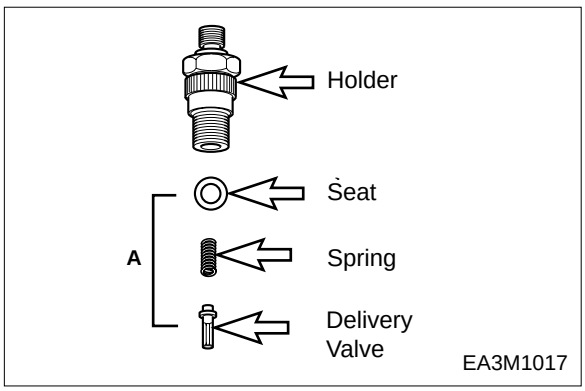
Torque	7.5 ~ 8.5 kg·m



- Install the oil delivery pipe and return pipe.
- At the same time, install the oil delivery pipe which feeds oil to the sea water pump.

(B) How to check the fuel injection timing exactiy

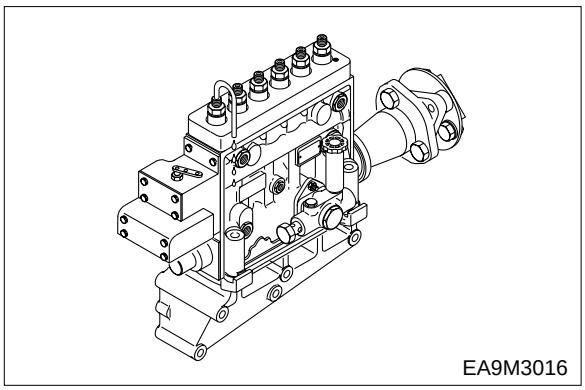
- To confirm the fuel injection pump timing, put the cylinder No. 6 in the overlap TDC position. And then remove the seat, spring and delivery valve from No. 1 plunger of the injection pump to check whether the fuel ejection or not from the injection pipe visually.



- Assemble the holder and pipe except seat, spring and delivery valve (“A” parts).

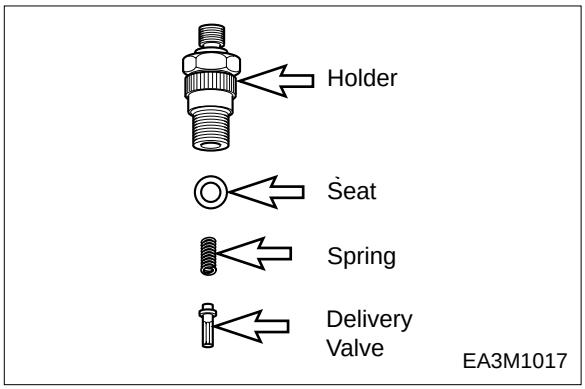
Holder Torque	4 ~ 4.5 kg·m

- Turn the crank pulley clockwise slowly on pumping the priming pump to be continues simultaneously and you can see the point that fuel falls down by one drop per every 5 or 6 seconds from the fuel pipe No. 1. This point is the very fuel injection timing degree.


EA9M3016

- After confirming the fuel injection timing, reassemble the holder and inner parts including seat, spring and delivery valve.

Holder Torque	4 ~ 4.5 kg·m



EA3M1017

- Connect the No. 1 fuel injection pipe and tighten as specified torque.

Fuel pipe nut Torque	3 ~ 3.5 kg·m

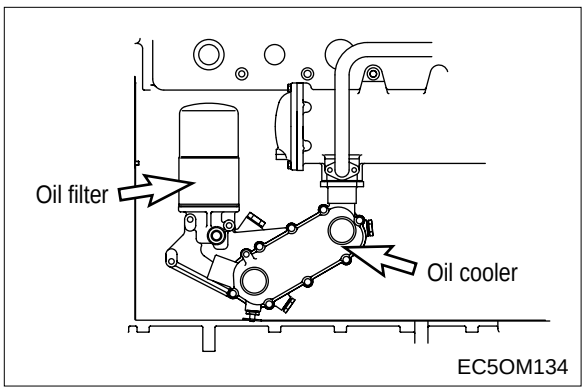
Caution : *Do not too tighten the delivery valve holder to prevent the rack mal function of the fuel injection pump.*
In case of exchanging the injection pump, be sure to fill the engine oil in the governor before engine starting.

<Oil capacity of injection pump>

L136/T/TI AD136/T/TI	L086TI AD086TI
0.5 LIt.	0.7 Lit.

6.3.28. Oil cooler & oil filter

- After assembling the oil cooler onto the oil cooler housing, tighten the mounting bolts of the oil cooler assembly in the cylinder block inserting a new gasket.
- Lightly oil the O-ring and turn the oil filter cartridge until its O-ring is contacted against the sealing face of the oil filter head. And then turn the oil filter cartridge 3/4~1 turn more with hands or a filter wrench.



EC5OM134

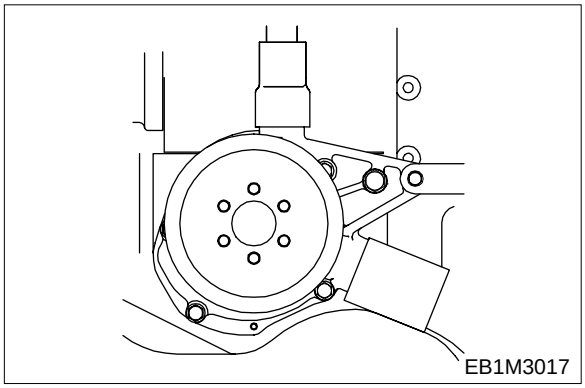
- Connect the cooling water pipes to the water pump and the heat exchanger.

6.3.29. Water pump

- Mount a new gasket.
- Install the water pump on the cylinder block and tighten the assembling bolts with specified torque.

Torque	2.2 kg·m

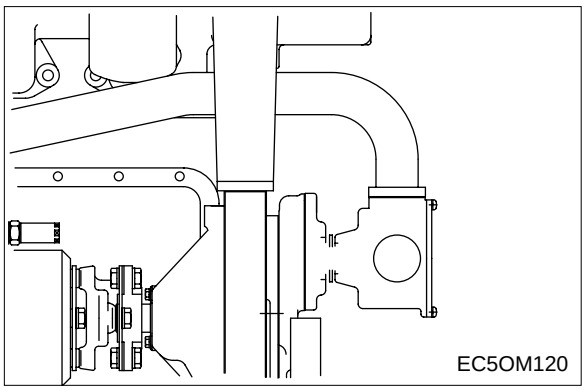
- Connect cooling water pipe and the expansion tank each other.


EB1M3017

6.3.30. Sea water pump

- Mount a new gasket.
- Install the sea water pump on the timing gear case cover and tighten the assembling bolts with specified torque.

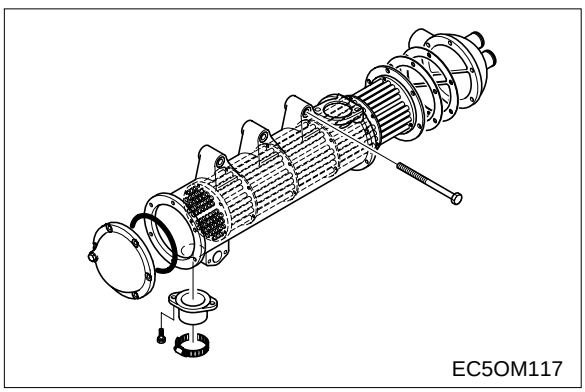
Torque	4.4 kg·m


EC5OM120

6.3.31. Heat exchanger

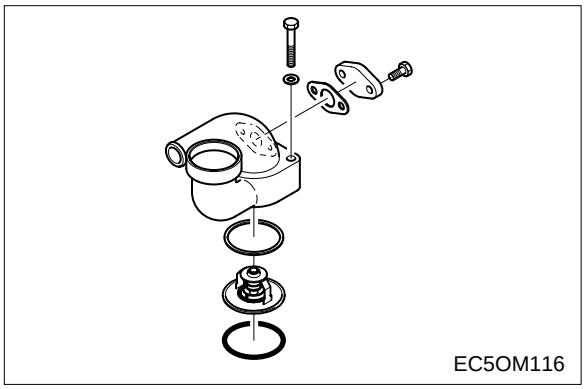
- Install the heat exchanger on the flywheel housing, and tighten the fixing bolts with specified torque.

Torque	4.4 kg·m


EC5OM117

6.3.32. Thermostat

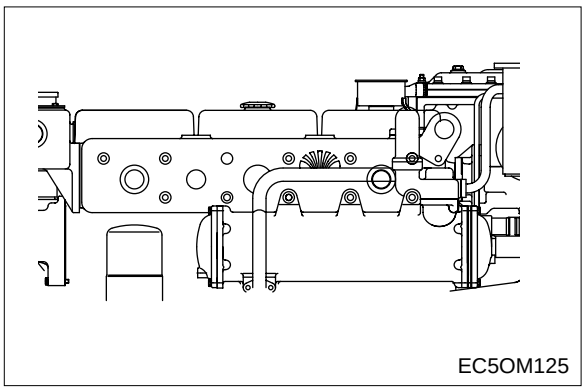
- Install the thermostat.
- Fit the new gasket on the thermostat housing, then assemble the thermostat housing with mounting bolts.
- Assemble the hose clamps in both sides of the heat exchanger and cooling water pipe


EC5OM116

6.3.33 Exhaust manifold

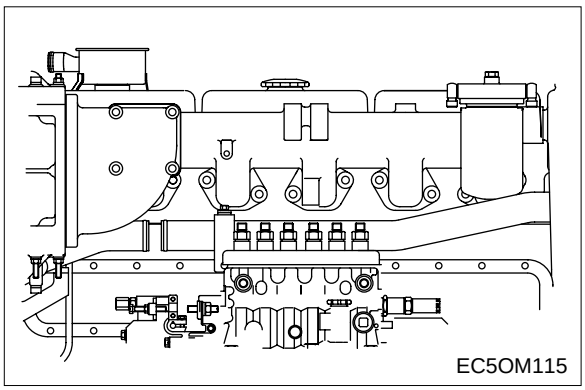
- Assemble the exhaust manifold with steel gasket in order to be installed in the small hole between two holes of the gasket upward and be sure to check the squared port of the gasket whether the square port of the cylinder head is aligned before assembling.
- Tighten the fixing bolts with specified torque.

Torque	M10 (Upper row)	4.4 kg.m
	M12 Lower row)	8.0 kg.m


EC5OM125

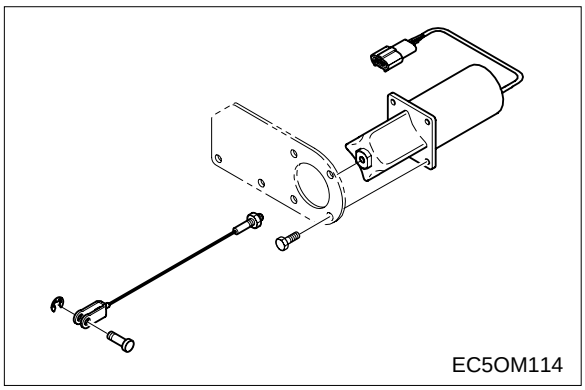
6.3.34. Intake manifold

- Assemble the intake manifold including the gasket.
- Connect the air hose to the boost compensator of the fuel injection pump.


EC5OM115

6.3.35. Stop solenoid (L086TI)

- Assemble the brackets on the injection pump body.
- Install the stop solenoid and tighten the fixing bolts.
- Connect the tie rod to fuel feed pump and stop solenoid.

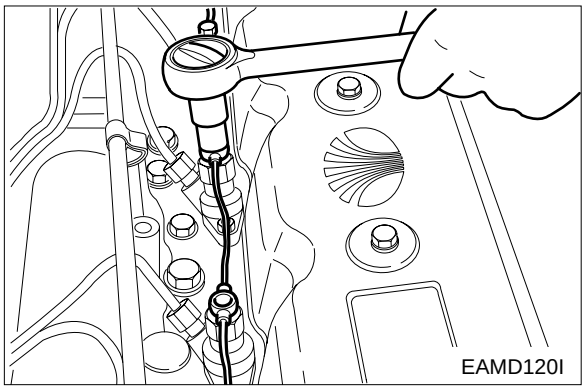

EC5OM114

6.3.36. Injection pipe

- Semi-assemble nuts at both ends of the fuel high pressure pipe and tighten them up one by one to specified torque.

Torque	3.0 kg·m

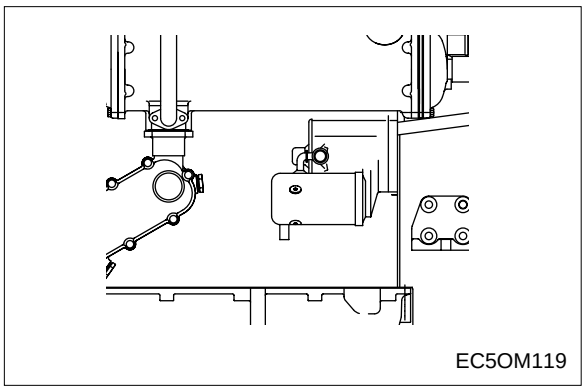
- Tighten the hollow screws to assemble the fuel return pipe.
- Assemble the fuel return hose to the fuel injection pump.


EAMD120I

6.3.37. Starter

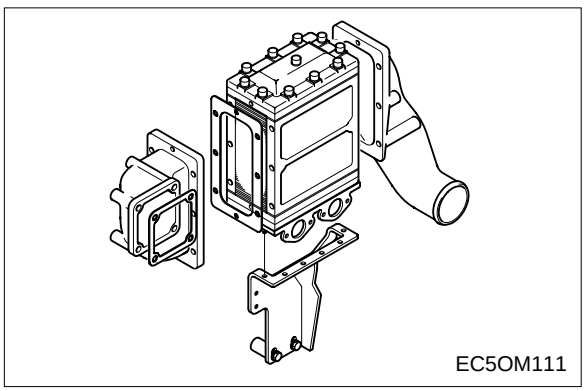
- Assemble the starter in position on the flywheel housing.

Torque	8.0 kg·m


EC5OM119

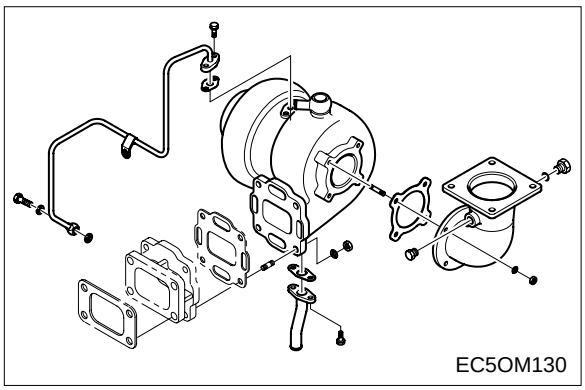
6.3.38. Intercooler

- After sub-assembling the air inlet & outlet pipe and sea water inlet & outlet cooling water pipe in the heat exchanger separately assemble the intercooler assembly on the bracket of the heat exchanger
- Insert the hoses each pipe and clamp the hoses separately.


EC5OM111

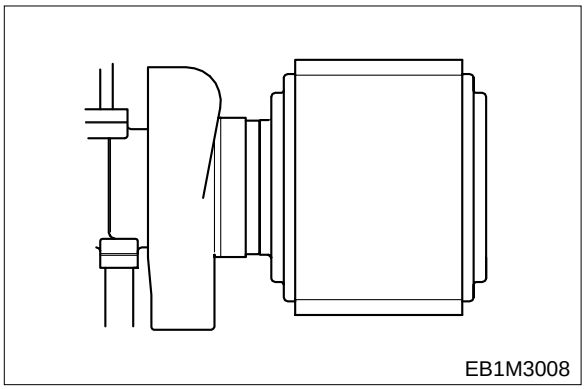
6.3.39. Turbocharger

- Insert a new gasket on the exhaust outlet pipe and mount the turbocharger.
- Install the oil supply & return pipe.
- Clamp the rubber hose connected to the air inlet pipe of the inter cooler, and assemble the cooling water inlet & outlet pipe.


EC5OM130

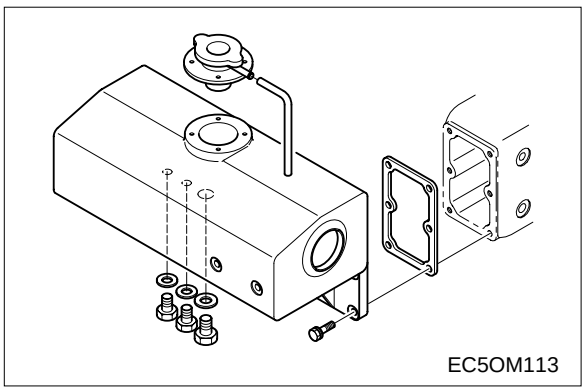
6.3.40. Air cleaner

- Assemble the air cleaner and tighten the bolt and nut of clamp properly
- Finally install the air filter element.


EB1M3008

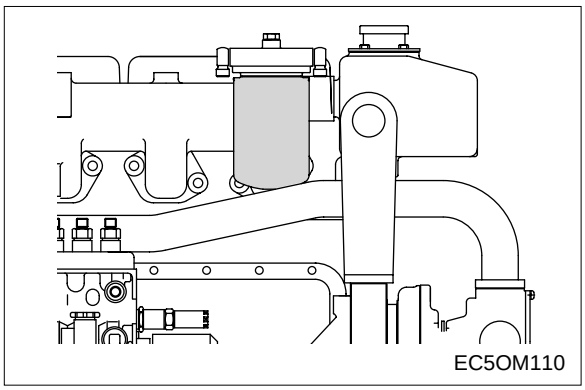
6.3.41. Expansion tank and Reservoir tank

- Assemble the expansion tank and rubber hose for by-pass pipe, and then tighten the clamp.
- Finally assemble the reservoir tank using holder and connect the hose between the expansion tank and reservoir tank.


EC5OM113

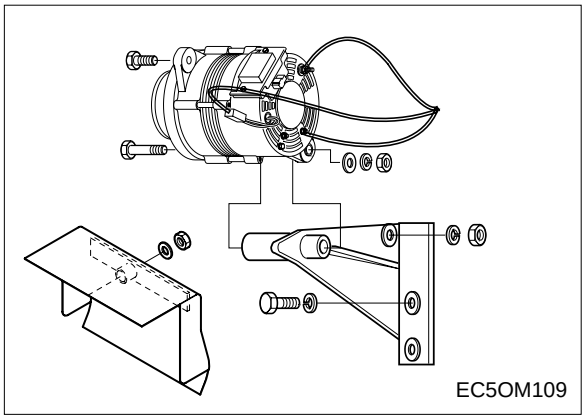
6.3.42. Fuel filter

- Assemble the fuel filter on the right of intake manifold as figure.
- Assemble the fuel feed hose according to the direction of the arrow impressed on the fuel filter head so that fuel can be fed in the sequence of **FUEL FEED PUMP R FUEL FILTER R FUEL INJECTION PUMP.**


EC5OM110

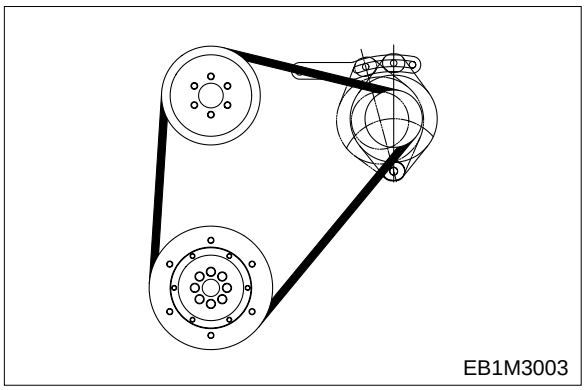
6.3.43. Alternator

- Install the alternator mounting bracket.
- Assemble the alternator and protector.



6.3.44. V - Belt

- Install the V-belt on the crank pulley and alternator.
- Adjust the V-belt tension using the tension adjusting bolt.



6.4. Break-in After Maintenance

Because the sliding parts of a new or an overhauled engine are not lapped enough, the oil film can be destroyed easily by overload or over-speed and the engine life time may be shorten. Therefore the operator must follow the things of **“3.3 Engine Break-in”** by all means.

7. Main Parts Maintenance

7.1. Lubricating System

Lubricating oil pumped by the gear oil pump in the oil pan is filtrated in the oil filter through oil cooler.

This filtrated oil passed on the main oil gallery of the cylinder block where is distributed to lubricate the various sliding parts, fuel injection pump, and turbo-charger etc also in order to ensure normal engine performance.

7.1.1. Specifications

Item	Specifications
Lubricating system	Forced pressure circulation
Oil pump type	Gear type
Relief valve opening pressure	10 ± 1.5 kg/cm^2
Bypass for oil cooler Opening pressure	5+1 kg/cm^2
Adjusting valve for spray nozzle Opening pressure	1.5 ~ 1.8 kg/cm^2
Oil filter type	Full flow
Bypass for filter element	Cartridge Type
Valve opening pressure	1.8 ~ 2.3 kg/cm^2
Bypass for entire oil filter Valve opening pressure	4.0 ~ 4.8 kg/cm^2

7.1.2. Oil pump

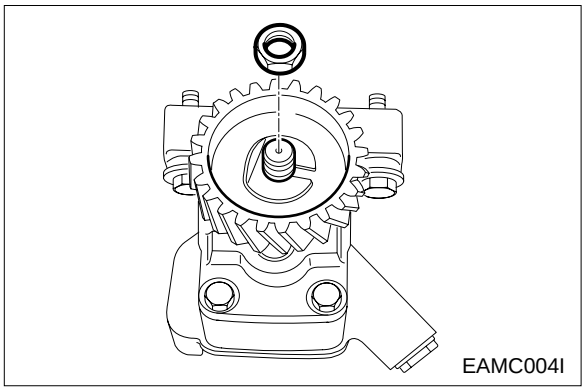
- **Disassembly**

(1) Disassembly of oil pump drive gear

a) Unscrew the screw and disassemble the oil relief valve.

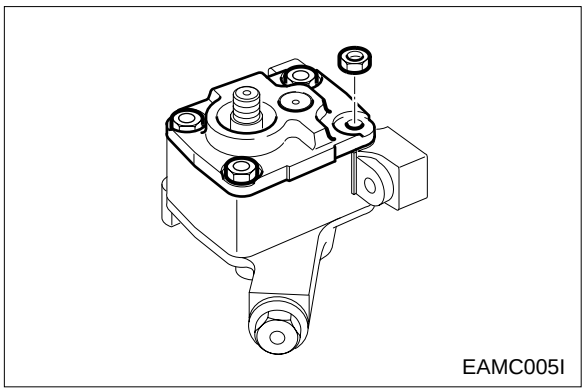
b) Unfold the washer for the oil pump drive gear fixing nut and remove the nut.

c) Disassemble the drive gear.


EAMC004I

(2) Remove the oil pump cover fixing nuts and disassemble the oil pump cover.
The oil pump cover is fixed with the two dowel pins.

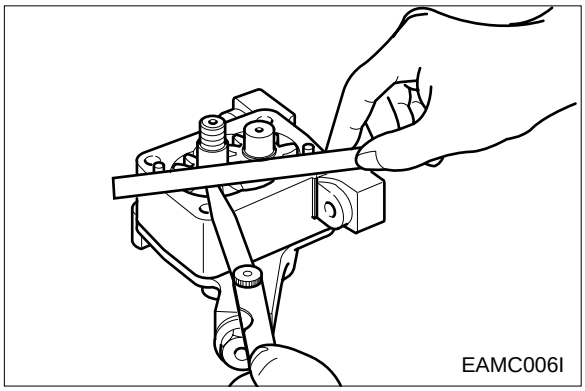
(3) Disassemble the drive and driven gear.


EAMC005I

- **Inspection and correction**

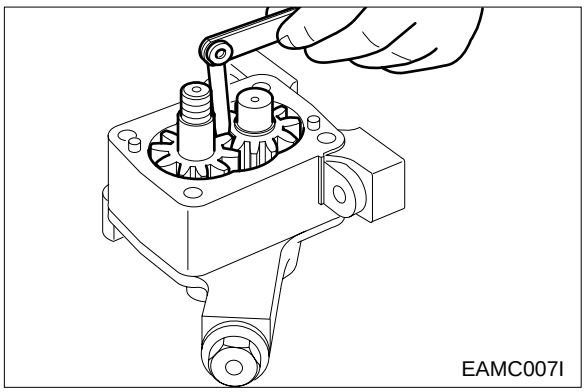
(1) With steel ruler and feeler gauge, measure the axial end play of the oil pump gear. Replace if the measured value is beyond the limit.

Limit	0.025 ~ 0.089 mm


EAMC006I

(2) With a feeler gauge, measure the amount of backlash between the oil pump drive gear and driven gear. Replace if the measured value is beyond the limit.

Limit	0.050 ~ 0.64 mm


EAMC007I

(3) Measuring clearance between drive shaft and bushing

a. Measure the outside diameter of the drive shaft and driven shaft, and replace if the measured values are less than the limit.

Limit	16.95 mm

b. Measure the inside diameter of the pump body bushing to determine the clearance between the bushing and shaft, and compare the measured value with the standard value to determine whether to replace or not.

<Clearance between oil pump shaft and bush>

Standard	0.032 ~ 0.077 mm

- **Re-assembly**

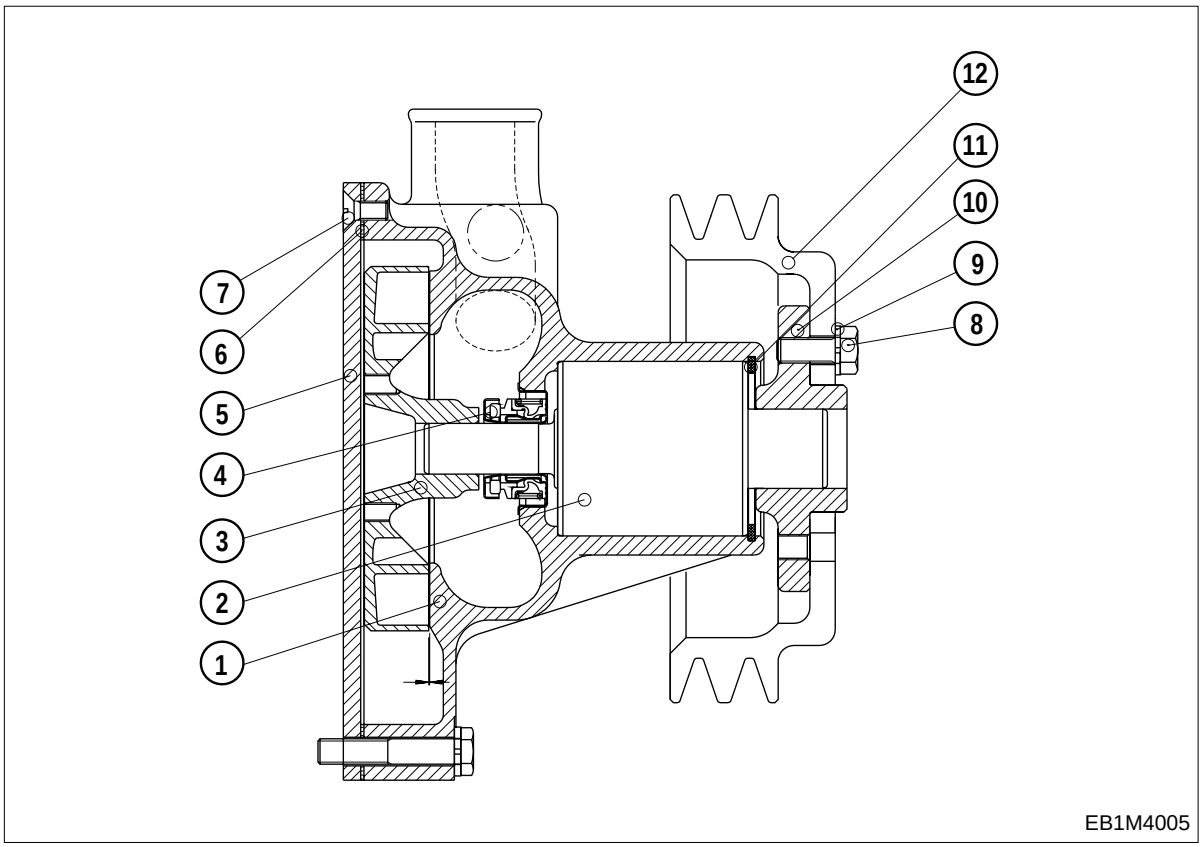
  (1) For re-assembly, reverse the disassembly sequence.

7.2. Cooling System

7.2.1. Cooling water pump

- Loosen the bolt (8) and remove the pulley (12).
- Unscrew the socket bolt (7) and detach the housing cover (5).
- After heating on the impeller (3) a little remove the impeller using a special jig.
- Detach the mechanical seal (4).
- Heat on the hub (9) little by little and then remove the hub using a removing jig.
- After detach the snap ring (11) remove the unit bearing shaft.
- Follow the re-assembly on contrary to order of disassembly.
- Exchange the oil seal (4) to a new one.
- If the used impeller is re-assembled, keep the clearance between the pump housing and impeller not to be more than 0.35 mm.

<Water pump assembly>



1. Water Pump Housing
2. Unit bearing & Shaft
3. Impeller
4. Mechanical Seal
5. Housing Cover
6. Gasket
7. Socket Bolt
8. Hex Bolt
9. Spring Washer
10. Hub
11. Snap Ring
12. Pulley

7.3. Fuel System

7.3.1. Injection pump

The components relating to the injection pump should be serviced at regular intervals as the plunger and delivery valve may be worn after a given length of time for use and cause the deterioration of the engine.

Make sure that servicing should be performed at the professional maintenance shop as authorized by Bosch or Zexel Company.

For adjustment of fuel injection volume, refer to the 'Specifications of fuel injection pump' described on the following pages.

1) L136, AD136

(1) Main Specification

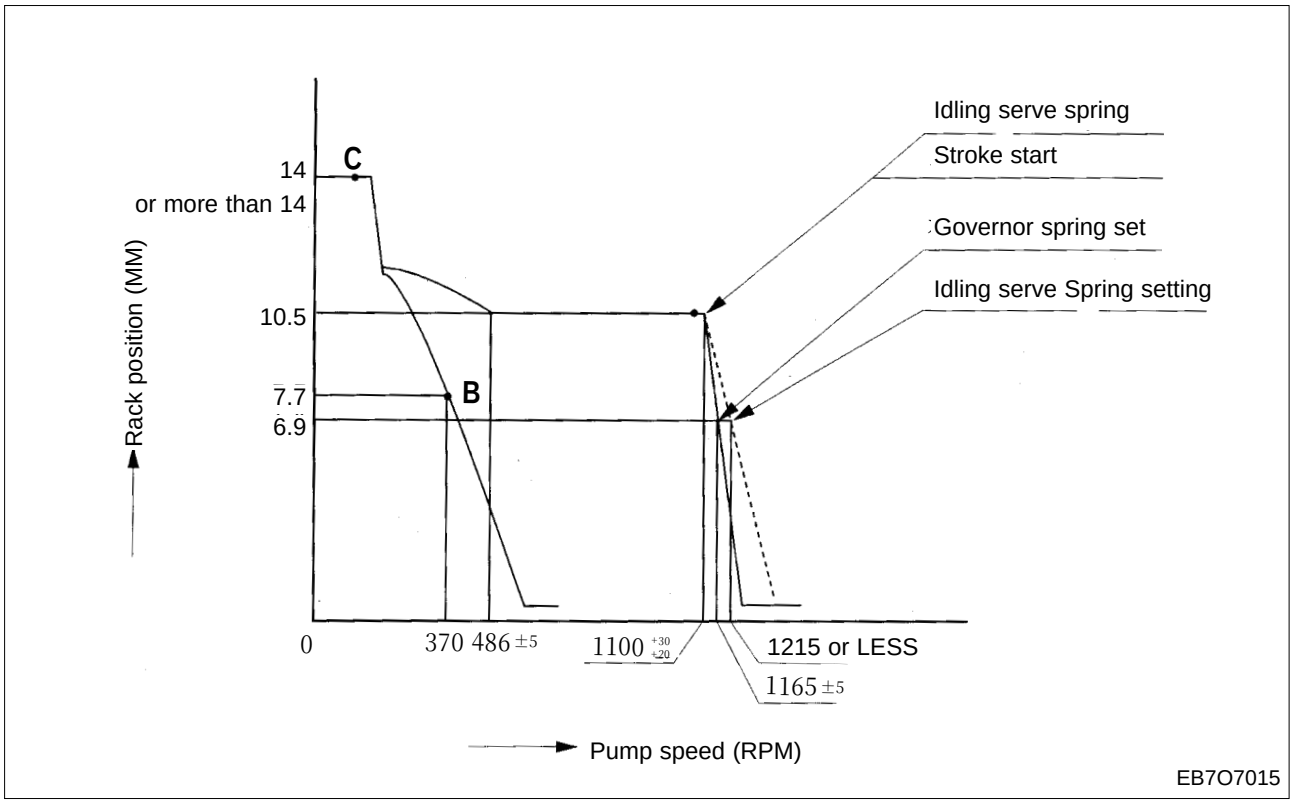
Fuel Injection Pump : 65.11101-7269A
Governor Type : RSV
Model Type : PES6AD
Cam Lift : 11 mm
Fuel Feed Pump : 105210-4830
Injection Timing : BTDC 18°±1°
Injection Order : 1-5-3-6-2-4
Rotating Direction : Clockwise (Viewed at driving gear side)

(2) Calibration Data

(A) Test condition for injection pump	Nozzle & Holder Ass'y		105780-8140	Opening pressure :175kg/cm²		
	Injection pipe(ID ,OD ,L)		-	∅8.0 x ∅2.0 - 600 mm		
	Test oil		ISO4113	Temperature :40 ± 5 ˚C		
(B) Engine standard parts	Nozzle & holder Ass'y		65.10101-7050	Nozzle (5 x ∅0.36)		
			-	214 + 8 kg/cm²		
	Injection pipe (ID, OD, L)		-	∅6 x ∅2.2 - 650 mm		
Rack diagram and setting valve at each point						
Refer to (3) Rack Diagram	Check point	Rack position (mm)	Pump speed (rpm)	Injection Q`ty on RIG (mm³ / 1,000st)		Press. (mmHg)
				(A) Test condition for inj. Pump	Max. Var. Bet. Cyl. (%)	
	A	10.5	1100	88.5 ± 2	± 2.5	Full
	B	7.7	370	11.5 ± 2	± 25	Idle
	C	≈	100	(135)	-	-

Balance Weight	740g	Lever ratio (min/max)	1 : 1.2
Governor spring	k = 7.2 kg/mm	Plunger	∅9.5 , 20 + 45 lead
Idle spring	k = 1.9 kg/mm	Delivery valve retraction volume	70 mm³/st, t=0.11
Idle sub spring	k = 3.0 kg/mm	Delivery valve opening pressure	23.1 kg/cm²
Start spring	k = 0.01 kg/mm	Delivery valve spring	k = 1.63 kg/mm
Max. discharge pressure	k = 3.4 kg/mm²	Feed pump	105210-5280 (KP-FP/KE-ADS)

(3) Rack Diagram



2) L136T, AD136T

(1) Main Specification

Fuel Injection Pump : 65.11101-7271A
Model Type : PES6AD
Governor Type : RSV
Fuel Feed Pump : 105210-4830
Cam Lift : 11 mm
Injection Timing : BTDC 18°±1°
Injection Order : 1-5-3-6-2-4
Rotating Direction : Clockwise (Viewed at driving gear side)

(2) Calibration Data

(A) Test condition for injection pump	Nozzle & Holder Ass'y	105780-8140	Opening pressure :175kg/cm²
	Injection pipe(ID ,OD ,L)	-	∅8.0 x ∅2.0 - 600 mm
	Test oil	ISO4113	Temperature :40 ± 5 ˚C
(B) Engine standard parts	Nozzle & holder Ass'y	65.10101-7050	Nozzle (5 x ∅0.36)
		-	214 + 8 kg/cm²
	Injection pipe (ID, OD, L)	-	∅6 x ∅2.2 - 650 mm

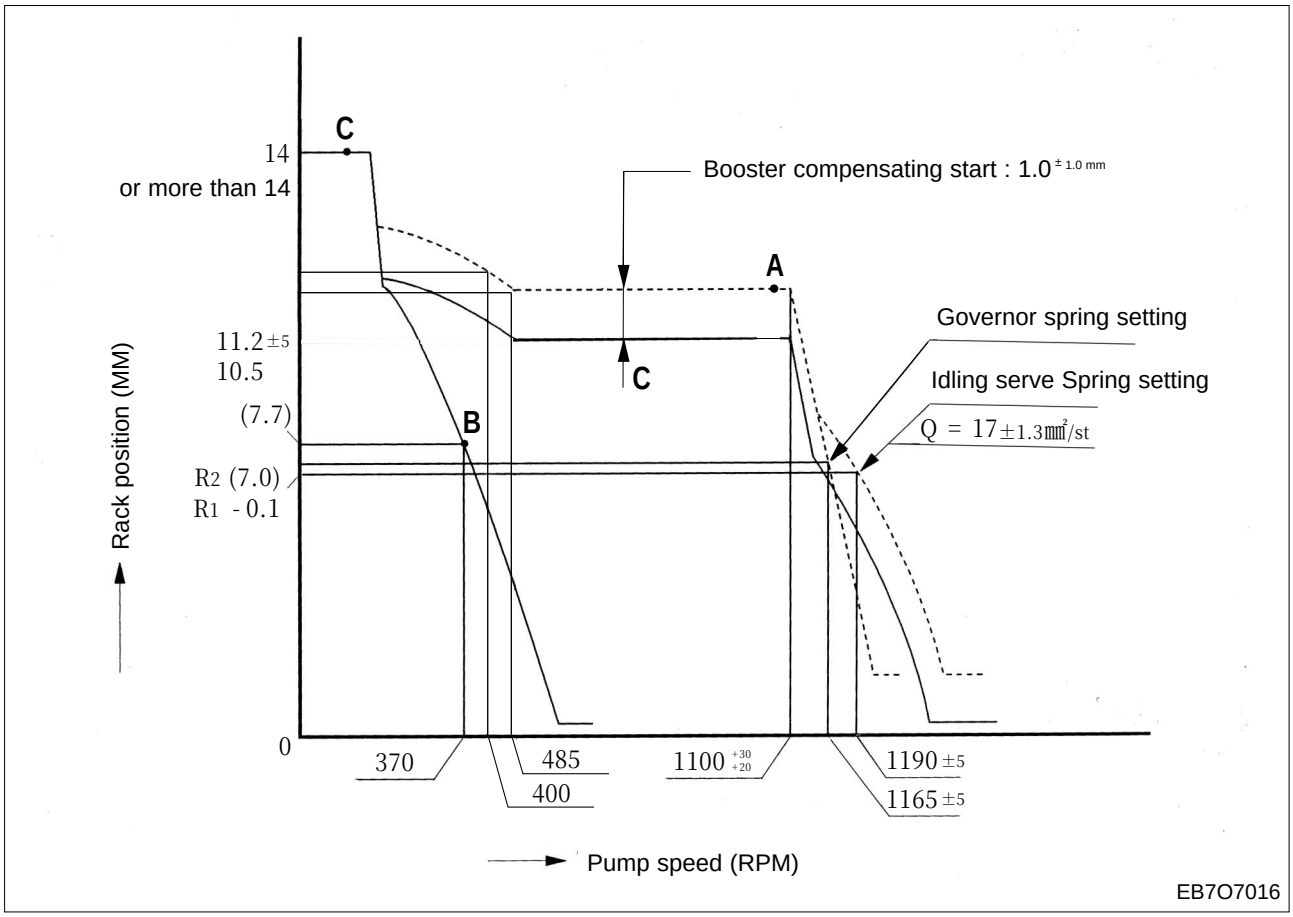
Rack diagram and setting valve at each point

Refer to (3) Rack Diagram

Check point	Rack position (mm)	Pump speed (rpm)	Injection Q`ty on RIG (mm³ / 1,000st)		Press. (mmHg)
			(A) Test condition for inj. Pump	Max. Var. Bet. Cyl. (%)	
A	10.5	1100	113.5 ± 2	± 2.5	Full
B	7.9	370	11.5 ± 2	± 25	Idle
C	≈	100	-	-	-

Balance Weight	740g	Lever ratio (min/max)	1 : 1.2
Governor spring	k = 7.2 kg/mm	Plunger	∅9.5 , 20 + 45 lead
Idle spring	k = 1.9 kg/mm	Delivery valve retraction volume	70 mm³/st, t=0.11
Idle sub spring	k = 3.0 kg/mm	Delivery valve opening pressure	23.1 kg/cm²
Start spring	k = 0.01 kg/mm	Delivery valve spring	k = 1.63 kg/mm
Max. discharge pressure	k = 3.4 kg/mm²	Feed pump	105210-5280 (KP-FP/KE-ADS)

(3) Rack Diagram



3) L136TI, AD136TI

(1) Main Specification

Fuel Injection Pump : 65.11101-7341
Model Type : PES6AD
Governor Type : RSV
Fuel Feed Pump : 105210-5610
Cam Lift : 12 mm
Injection Timing : BTDC 14°±1°
Injection Order : 1-5-3-6-2-4
Rotating Direction : Clockwise (Viewed at driving gear side)

(2) Calibration Data

(A) Test condition for injection pump	Nozzle & Holder Ass'y	105160-4370	Opening pressure : 175kg/cm²
	Injection pipe(ID ,OD ,L)	-	∅8.0 x ∅2.0 - 600 mm
	Test oil	Calibration oil	Temperature :40 ± 5 ˚C
(B) Engine standard parts	Nozzle & holder Ass'y	105160-4370	Nozzle (5 x ∅0.36)
		Calibration oil	214 + 8 kg/cm²
	Injection pipe (ID, OD, L)	∅6 x ∅2.0 - 650 mm	∅6 x ∅2.0 - 650 mm

Rack diagram and setting valve at each point

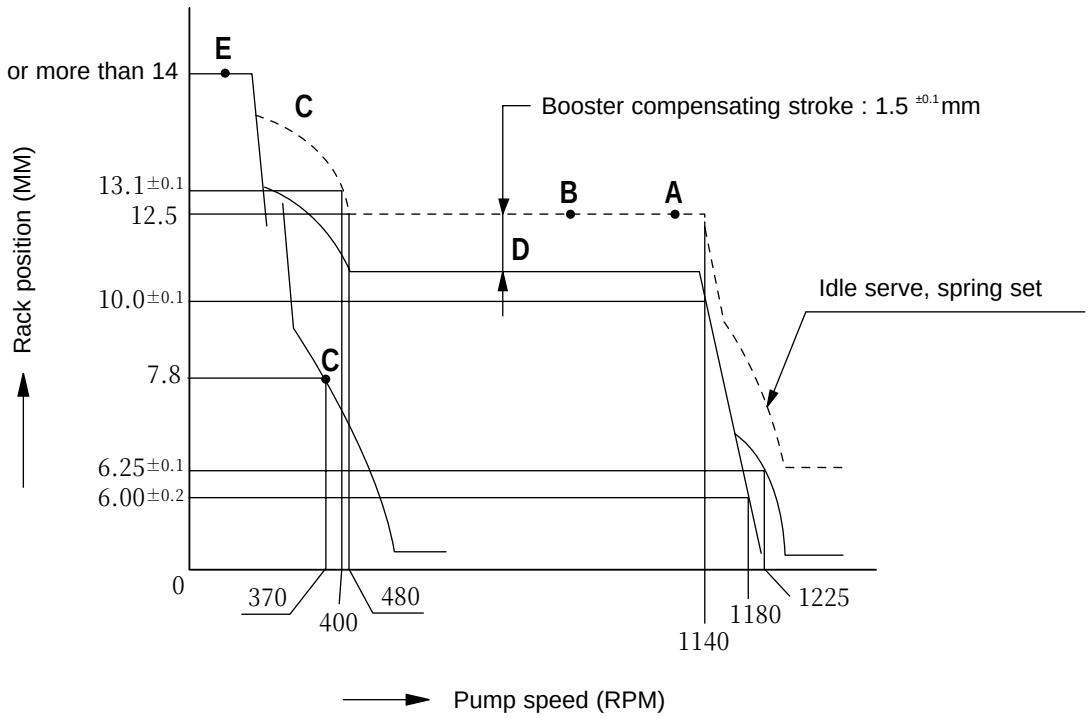
Refer to (3) Rack Diagram

Check point	Rack position (mm)	Pump speed (rpm)	Injection Q`ty on RIG (mm³ / 1,000st)		Boost Press. (mmHg)
			(A) Test condition for inj. Pump	Max. Var. Bet. Cyl. (%)	
A	12.5	1100	121 ± 2	-	More 500
B	(12.5)	750	(123.5)	-	
C	≈ 7.8	370	10 ± 1.5	-	-
D	R_1-1.5	600	(89.5)	-	-
E	more 14	100	(155)	-	-

R_1=12.5

Balance Weight	740g	Lever ratio (min/max)	1 : 1.2
Governor spring	k = 7.2 kg/mm	Plunger	∅9.5 , 20 + 45 lead
Idle spring	k = 1.9 kg/mm	Delivery valve retraction volume	70 mm³/st
Idle sub spring	k = 2.5 kg/mm	Delivery valve opening pressure	23.1 kg/cm²
Start spring	k = 0.01 kg/mm	Delivery valve spring	k = 1.63 kg/mm
Max. discharge pressure	k = 3.4 kg/mm²	Feed pump	105210-5610

(3) Rack Diagram



4) L086TIH, AD086TI

(1) Main Specification

Fuel Injection Pump : 65.11101-7311
Model Type : PE6P120/720RS3S
Governor Type : RSV 200/1300
Plunger : 134153-1420
Delivery Valve : 134110-1420
Fuel Feed Pump : 105237-5470
Cam Lift : 12 mm
Injection Timing : BTDC 15°±1°
Injection Order : 1-5-3-6-2-4
Rotating Direction : Clockwise (Viewed at driving gear side)

(2) Calibration data

(A) Test condition for injection pump	Nozzle & Holder Ass'y	105780-8140	Opening pressure :175kg/cm²
	Injection pipe(ID ,OD ,L)	-	∅8.0 x ∅3.0 - 600 mm
	Test oil	ISO4113	Temperature :40 ± 5 ˚C
(B) Engine standard parts	Nozzle & holder Ass'y	65.10101-7450	Nozzle (5 x ∅0.36)
		LRC6703709	214 + 8 kg/cm²
	Injection pipe (ID, OD, L)	65.10301-6049A 65.10301-6052A	∅6.35 x ∅2.2 - 650 mm

Rack diagram and setting valve at each point

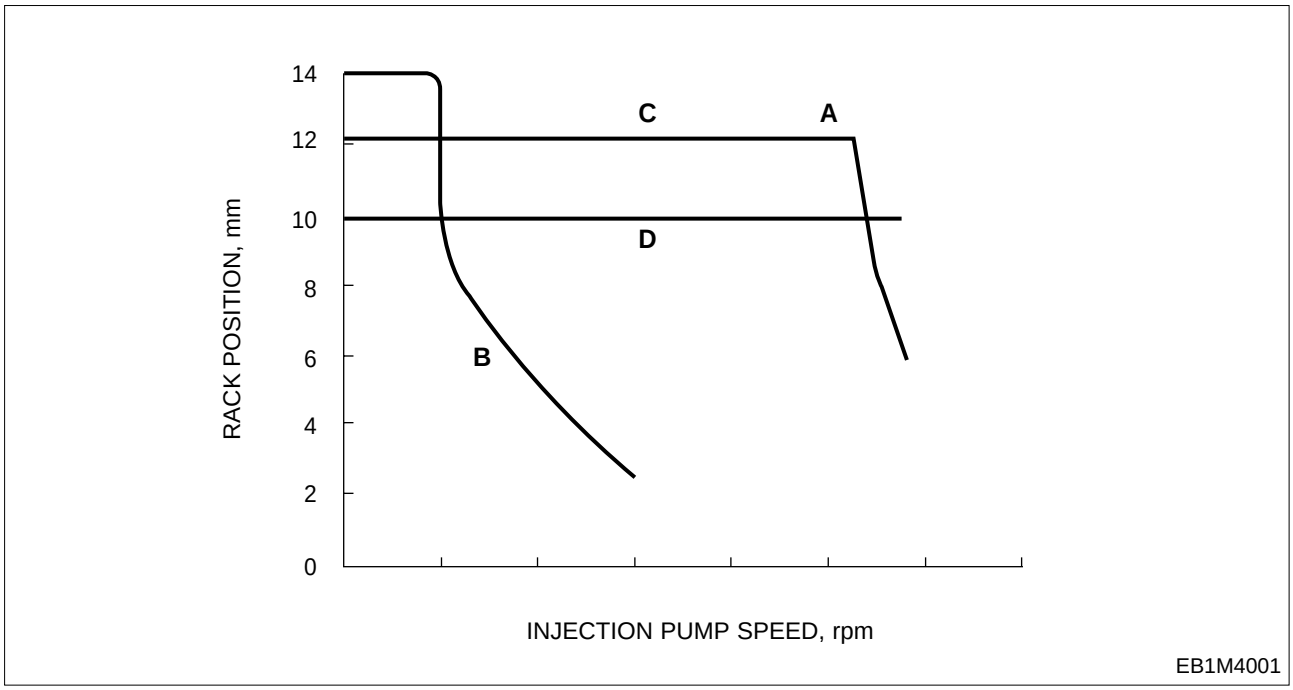
Refer to (3) Rack Diagram	Check point	Rack position (mm)	Pump speed (rpm)	Injection Q`ty on RIG (mm³ / 1,000st)		Press. (mmHg)
				(A) Test condition for inj. pump	(B) Engine standard parts	
	A	12.2	1050	169.5 ± 2.0	± 2	980≤
	B	(6.7)	315	10.0 ± 1.3	± 15	-
	C	12.2	500	(177)	-	980≤
	D	10.0	500	(103) ± 3	-	-
					-	-
					-	

Boost pressure dependent full - load stop (boost compensator spring operation point)

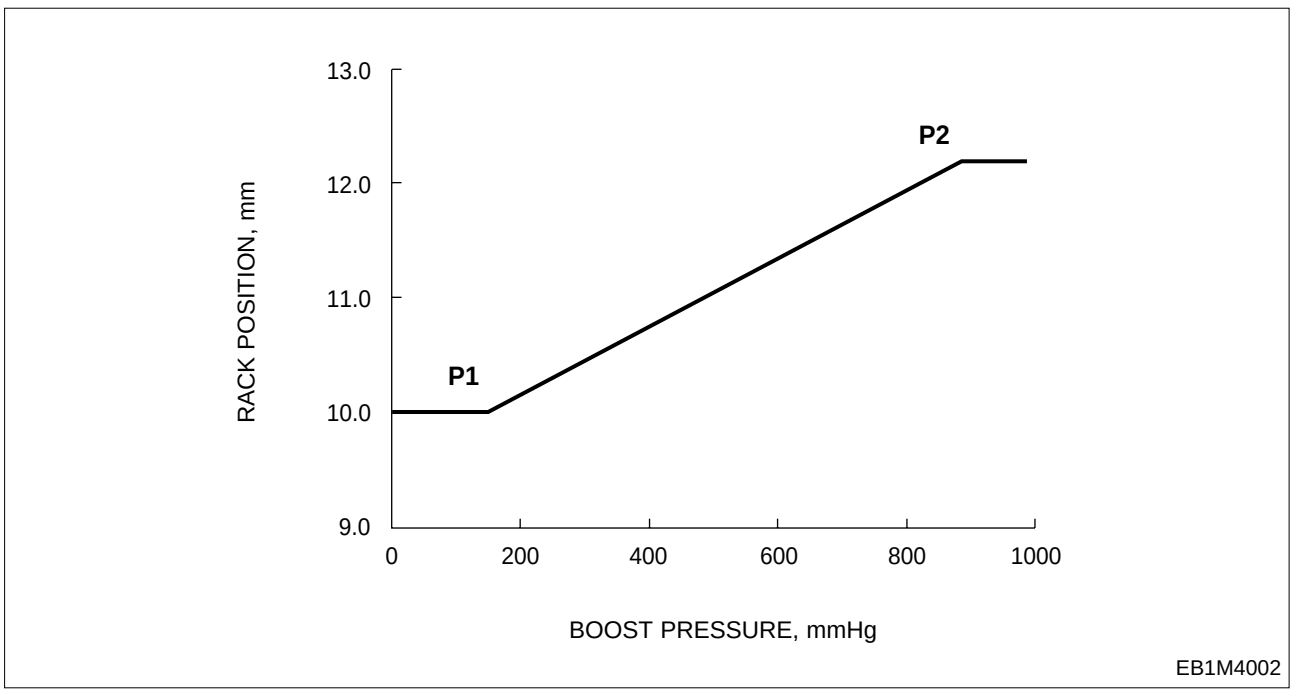
Refer to (4) Boost pressure	Check point	Rack position (mm)	Pump speed (rpm)	Injection Q'ty on RIG (mm³ / 1,000st)		Press. (mmHg)
				(A) Test condition for inj. pump	(B) Engine standard parts	
	P1	10.0	500	177	-	150
	P2	12.2	500	103	-	880
	-	-	-	-	-	-

Weight	Weight = 740kg	Lever ratio(min/max)	Min. speed 1 : 1.2 Max. speed 1 : 1.2
Governor spring	k = 7.2 kg/mm	Plunger	∅12 , 30 lead
Idle spring	k = 1.9 kg/mm	Delivery valve retraction volume	100 mm³/st, t=0.09
Idle sub spring	k = 1.2 kg/mm	Delivery opening pressure	18.5 kg/cm²
Start spring	k = 0.01 kg/mm	Delivery valve spring	k = 0.87 kg/mm
Boost compensator spring	k = 1.0 kg/mm	Feed pump	105237-5470 (NP-FP/KD-PS)

(3) Rack diagram



(4) Boost compensator pressure



5) L086TIM

(1) Main Specification

Fuel Injection Pump : 65.11101-7311
Model Type : PE6P120/720RS3S
Governor Type : RSV 200/1300
Plunger : 134153-1420
Delivery Valve : 134110-1420
Fuel Feed Pump : 105237-5470
Cam Lift : 12 mm
Injection Timing : BTDC 15°±1°
Injection Order : 1-5-3-6-2-4
Rotating Direction : Clockwise (Viewed at driving gear side)

(2) Calibration data

(A) Test condition for injection pump	Nozzle & Holder Ass'y	105780-8140	Opening pressure :175kg/cm²
	Injection pipe(ID ,OD ,L)	-	∅8.0 x ∅3.0 - 600 mm
	Test oil	ISO4113	Temperature :40 ± 5 ˚C
(B) Engine standard parts	Nozzle & holder Ass'y	65.10101-7450	Nozzle (5 x ∅0.36)
		LRC6703709	214 + 8 kg/cm²
	Injection pipe (ID, OD, L)	65.10301-6049A 65.10301-6052A	∅6.35 x ∅2.2 - 650 mm

Rack diagram and setting valve at each point

Refer to (3) Rack Diagram

Check point	Rack position (mm)	Pump speed (rpm)	Injection Q`ty on RIG (mm³ / 1,000st)		Press. (mmHg)
			(A) Test condition for inj. pump	(B) Engine standard parts	
A	12.4	1150	178.7 ± 5.0	Max. Power	-
B	8.1	700	19.1 ± 1.0	-	-
C	12.4	500	182.2 ± 3.0	-	-
D	10.0	500	99.5 ± 3.0	-	-
E	W/Cap	100	225.3 ± 3.0	-	-

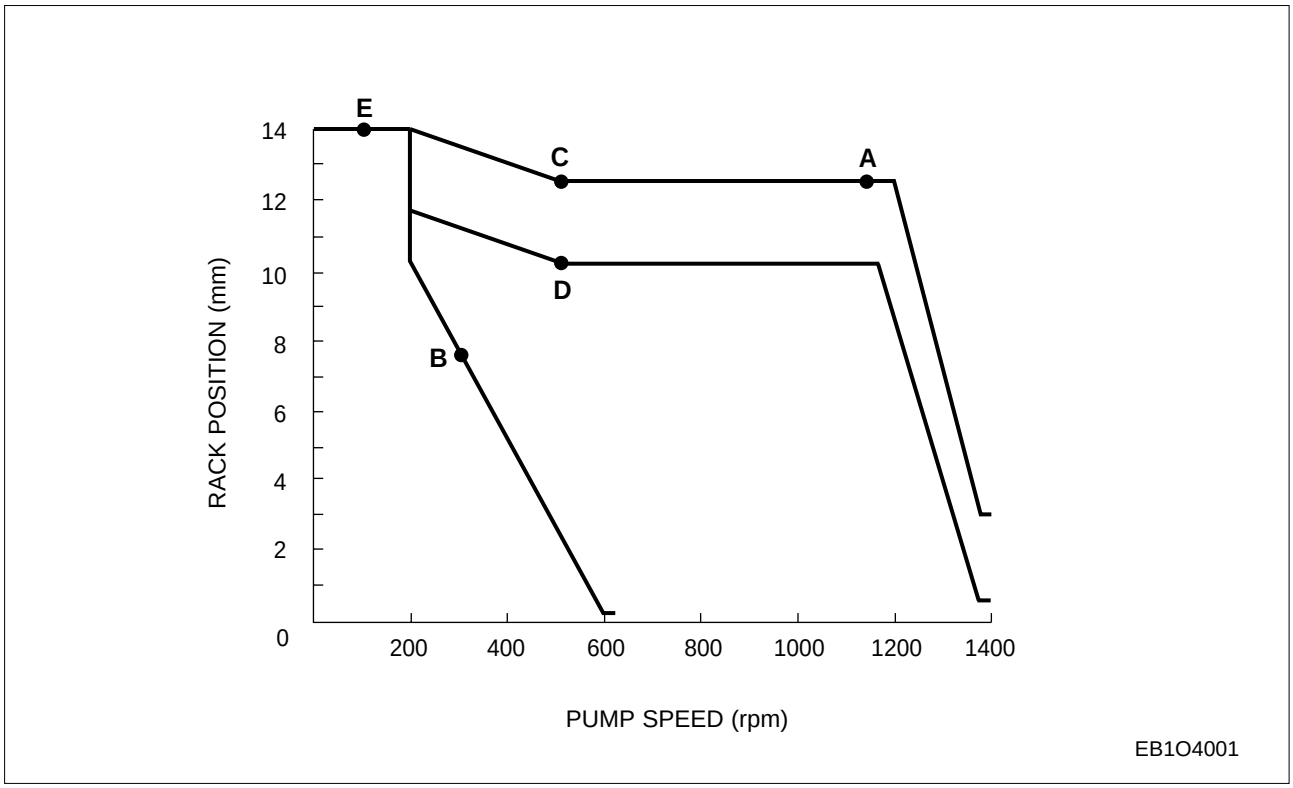
Boost pressure dependent full - load stop (boost compensator spring operation point)

Refer to (4) Boost pressure

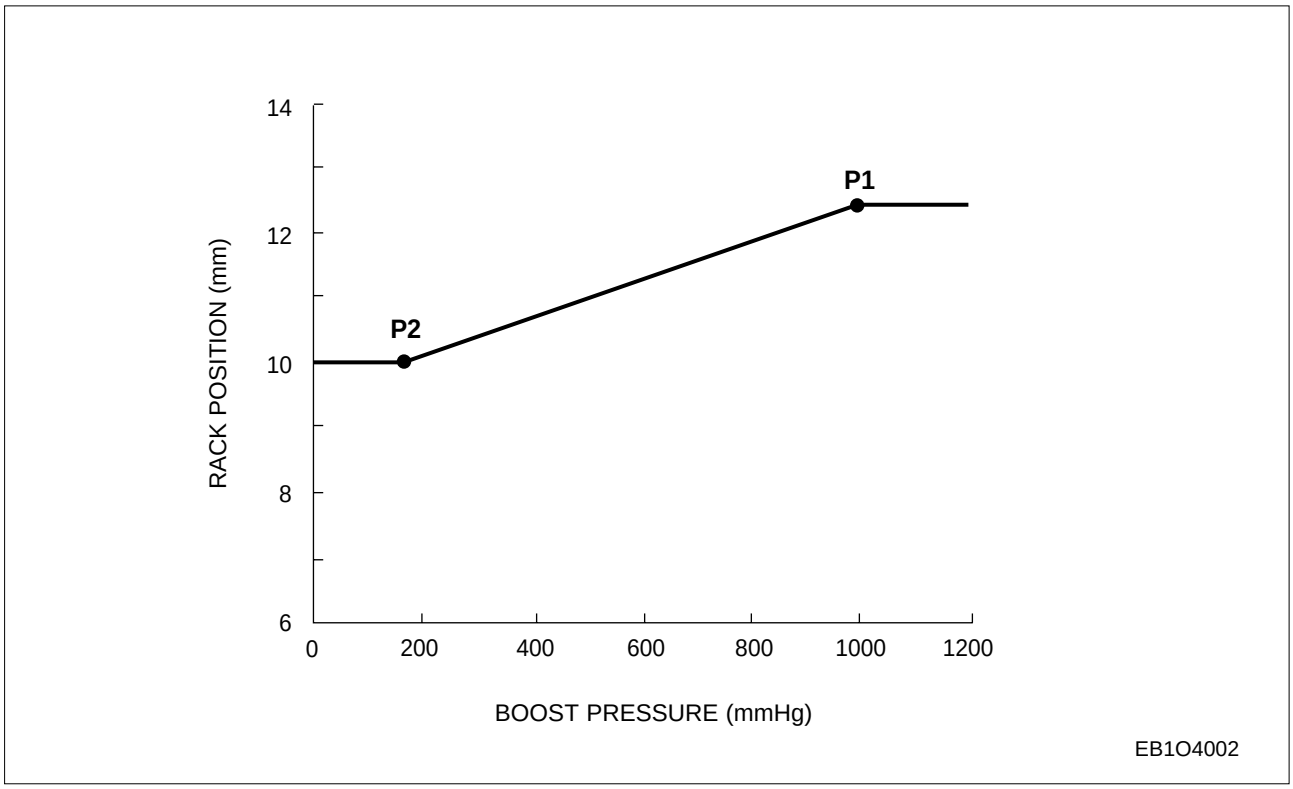
Check point	Rack position (mm)	Pump speed (rpm)	Injection Q'ty on RIG (mm³ / 1,000st)		Press. (mmHg)
			(A) Test condition for inj. pump	(B) Engine standard parts	
P1	12.4	500	178.7 ± 5.0	-	1,020
P2	10.0	500	99.5 ± 3.0	-	150
-	-	-	-	-	-

Weight	Weight = 740kg	Lever ratio(min/max)	Min. speed 1 : 1.2 Max. speed 1 : 1.2
Governor spring	k = 7.2 kg/mm	Plunger	∅12 , 30 lead
Idle spring	k = 1.9 kg/mm	Delivery valve retraction volume	100 mm³/st, t=0.09
Idle sub spring	k = 1.2 kg/mm	Delivery valve opening pressure	18.5 kg/cm²
Start spring	k = 0.01 kg/mm	Delivery valve spring	k = 0.87 kg/mm
Boost compensator spring	k = 1.0 kg/mm	Feed pump	105237-5470 (NP-FP/KD-PS)

(3) Rack diagram



(4) Boost compensator pressure



7.3.2. Electric governor system

1) AD136/T/TI

Governor system for fuel injection pump consists of “Integral Actuator” and “ Speed Control Unit”.

(1) ACAD176 Series Electric Actuator

- **Introduction**

The ACD176 SERIES electric actuator is designed to mount directly on a Bosch “A” size fuel injection pump, with a left hand rack, in place of the mechanical governor. When the ACE176 is installed on the fuel pump, an optimum performance, long life fuel control system results. An external fuel shut off lever is available to manually override the actuator’s control. Also provided is an adjustable internal maximum fuel limit

The ACD176 can control fuel pumps of up to 6 cylinders.
The actuator was designed with two isolated chambers. The upper chamber is wet with oil and contains the connection to the fuel rack and an optional manual shut off mechanism.
The sealed lower chamber contains the electromagnetic components.

This design eliminates the possibility of magnetic pa other oil contaminants interfering with the operation eletric actuator. Unreliable devices such as bell sliding seals are not used so that no maintenance is The designed ieft of the actuator is typically longer of the engine.

Available actuator models : ACD176-12 (12V w/o manual shutoff)
ACD176-24 (24V w/o manual shutoff)
ACD176A-12 (12V w/ manual shutoff)
ACD176A-24 (24V w/ manual shutoff)

The 176 SERIES actuator can also be supplied with tion sensor that allows the actuator to be used in a agement system. Contact GAC for assistance.

- **Specifications**

Performance

Force ..... (see Figure 1) ..... 6.2 lb. (27.5 N)
Operating Stroke..... 0.80 in. (21 mm)
Response Time (10 ~ 90 %, 2 - 19 mm) ..... 35 msec.

Electrical Power Input

Operating Voltage ..... 12 or 24V DC
Nominal Operating Curren.....12V DC version ..... 4.0 A
24V DC version ..... 2.0 A
Maximum Current .....12V DC version ..... 5.8 A
24V DC version ..... 3.1 A

Environmental

Operating Temperature ..... -40 to +95 °C (-40 to +200 °F)
Relative Humidity ..... up to 100 %
Vibration ..... 20 g, 20 - 500 Hz
Shock ..... 20 g @ 11 msec.

Physical

Dimensions ..... See Figure 2
Weight ..... 4.75 lb. (1.9 kg.)
Mounting ..... Requires camshaft bearing retainer it
BOSCH P/N 1415522036

● Installation

Perparing the fuel injection pump

If the fuel injection pump is equipped with a mechanical governor, it must be removed. GAC recommends that this modicication be performed by a qualified fuel injection service facility. The following procedure lists the general steps required to remove the mechanical governor.

Note :
Be prepared to collect the oil that will be released from the mechanical governor.

1. Remove the rear housing from the mechanical governor and disconnect the governor linkage from the fuel rack. Remove the flyweight assembly. A specical tool is required.

2. Remove the intermediate governor housing. This leaves only the rack and camshaft protruding from the pump.

3. Install the camshaft bearing retainer plate to provide support to the bearing formerly held by the governor housing.
This plate must have countersunk holes for the mounting screws.

Installing the actuator

All hardware needed to attach the actuator to the pump is located in kit KT288 supplied with the actuator.

1. The mounting surface on the pump must be clean. Attach the link(1) to the left-hand side of the fuel rack with a M5 X 10 mm screw(2) that includes a patch of locking adgesive.
Tighten the screw to 3 - 4 NM so that the pump and torque to 5 - 6 NM.

2. Remove the two lower screws of the bearing retainer plate and replace them with the retainers(3). Attach the retainers with their shorter end threaded into the pump and torque to 5 - 6 NM.

3. Temporarily place the actuator over the rack and retainers and onto the pump face. Check that the actuator contacts both the pump face and shoulders of the retainers. If necessary, use M6 spring washers to shim the retainers. The upper and lower mounting points of the actuator must be equally supported. Remove the actuator from the pump.

4. Remove both of the actuator covers. DO NOT remove or loosen the lever(16) from the actuator shaft. Place the o-ring seal(4) into the groove on the mounting face of the actuator. Apply a small amount of grease to the o-ring to hold it in place.

5. Swing the armature out of the actuator so that the lever(16) is out of the way. Guide the actuator over the rack and onto the lower mounting retainer studs. Attach the top of the actuator to the pump with the M8 X 16 mm socket head screw(5), lock washer(6), and flat washer(7). Use M6 hex nuts(8) and spring washers(9) to secure the portion of the actuator. Torque the screw to 6 - 8 NM and nuts to 5 - 6 NM.

6. Pull on the rack so that it is as far out of the pump as possible. Check that it moves freely. Place the return spring(10) over the rack. Place the spring retainer / shut off plate assembly(11, 12) and the M10 locking nut(13) over the threads on the rack link(1). The flats on the shut off plate(12) must engage the flats on the link(1). Tighten the nut to 6 - 8 NM and insure that the shut off plate is vertical and secure.

7. Test the engagement of the shut off mechanism with the rack linkage. Swing the lever back into the actuator. Push on the armature to insure that the rack linkage operates smoothly and returns immediately when released. Reattach the lower actuator cover(23) and tighten the screws(20) to 4 - 6 NM.

8. Loosen the fixation screw(17) so that the bearing(18) can be adjusted in its slot. Adjust the bearing so that it pushes the rack0.5 - 0.7 mm away from its stop position. Hold the bearing in this position and tighten the screw(17) to 4 - ? NM. The rack is now adjusted so that premature wear of the gear segments is avoided. Confirm that the operating lever screw(19) is tightened to 12 - 13 NM. Inspect the assembly to make sure all screws are tight.

9. Ther lever has a maximum fuel adjustment set screw(14). This screw is used to restrict the fuel rack from 1 to 14.5 mm.

Caution :
Setting fuel levels above 14.5 mm can cause the screw to hit the back cover, which can restrict minimum fuel. This can lead to a dangerous condition. Do not operate the engine this way. Fuel levels above 14.5 mm require a shorter stop screw, M6 X 25mm.

With the fuel pump operating on the engine, the maximum fuel setting can be set to prvide specific horsepower. Once this setting is made tighten the lock nut(15) on the stop screw to 5 - 6 NM.

10. Move the manual shut off lever to the stop position and insure that the fuel is completely shutoff and the engie stops.

11. With the engine shut down, install the upper chamber cover with the four scew(20, 21) and lock washers. Note that when installed, the cover must not hit the internal lever or its stop screw. Tighten the screws to 2 - 3 NM. Check for any oil leaks. Lock wire the screws for tamper resistance.

Caution :
The engine should be equipped with an independent shut down device to prevent overspeed whic can cause equipment damage or personal injury.

Caution :

Adjusting the fuel pump is an essential part for performance and endurance of engine, therefore operation and maintenance should be performed only by specialized engineer.

WIRNING

The ACD176 actuator is pre-wired for 12 or 24V DC operation. Use the included cable harness to connect the actuator to the speed control unit. The cable may be lengthened as necessary to fit the specific application. Use the comparable size wire to extend the cable harness. DO NOT use an ACD176 on a 32V system, contact the factory for assistance.

Figure 1 ACD176 Fuel Rack Force vs. Stroke

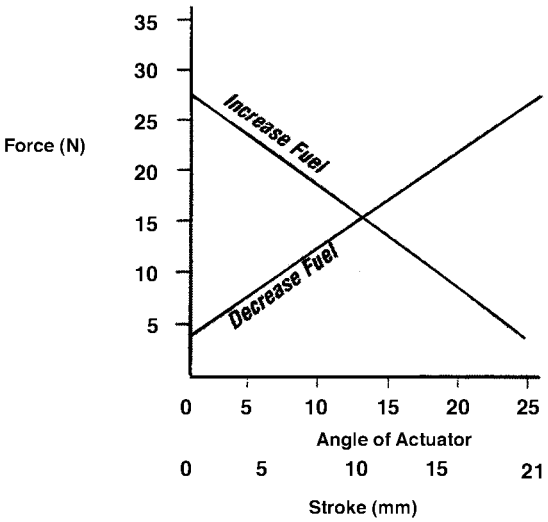
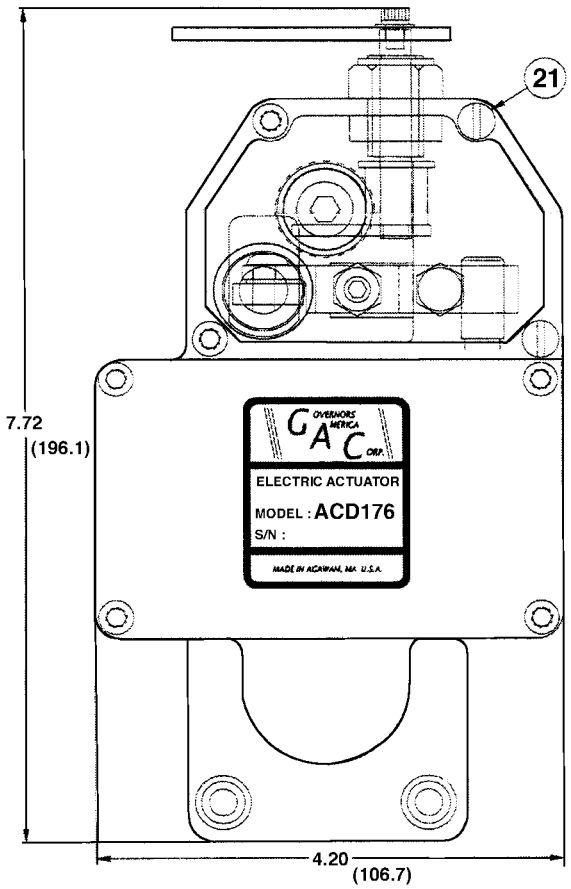
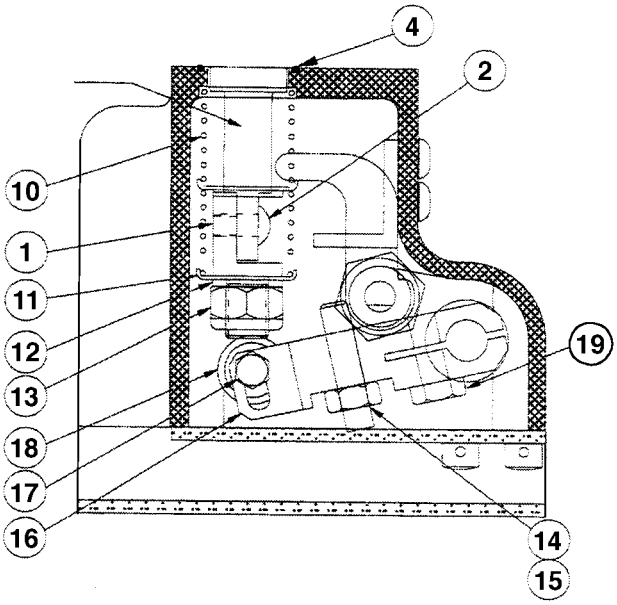
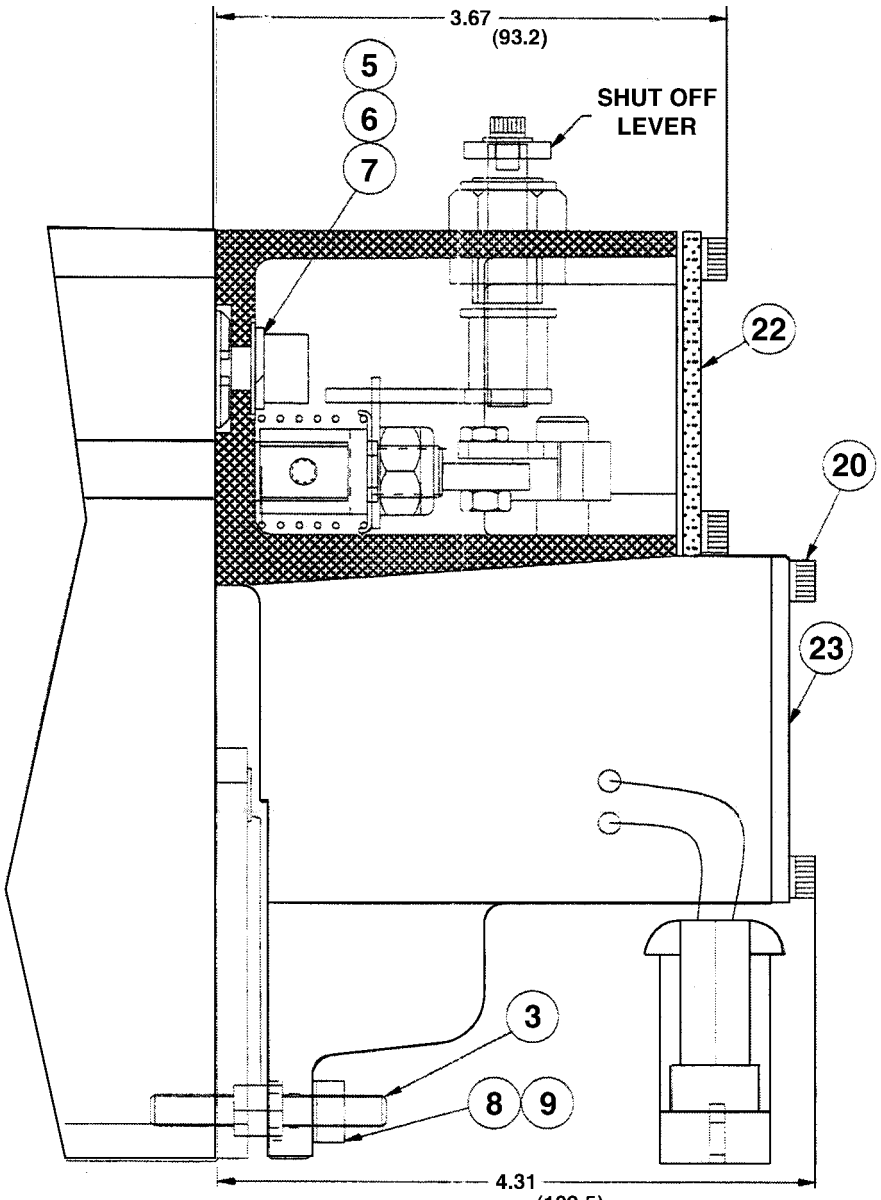


Figure 2 ACTUATOR OUTLINE





EA4O9001



PACKARD CONNECTOR 15300002
WITH TERMINALS 12048159

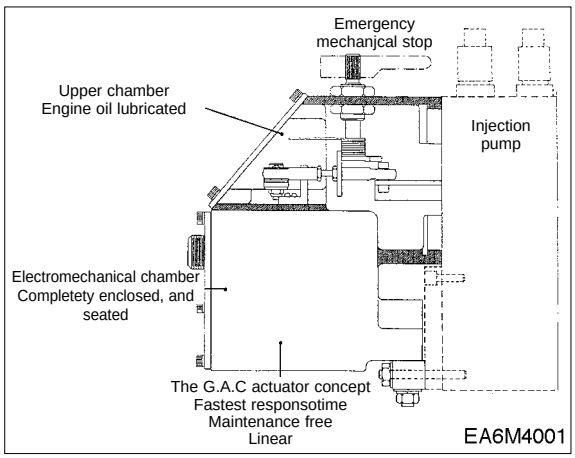
MATING CONNECTOR 15300027
WITH TERMINALS 12077411
(NOT INCLUDED)

EA4O9101

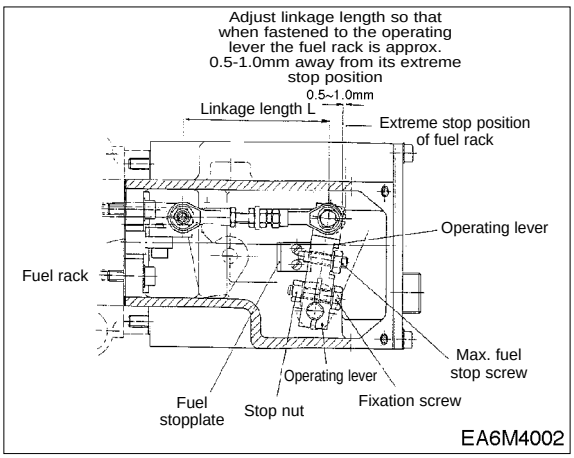
2) AD086TI

Governor system for fuel injection pump consists of “Integral Actuator” and “Speed Control Unit”.

(1) Integral Actuator



<Side View>



<Top View>

● **Functions of Actuator’s component**

1. Emergency stop lever

It is emergency stop lever operated by manual at emergency.

2. Upper control chamber

The cover for controlling the inside is installed.

3. Electro control chamber

Operating lever is started by the electric signal generated in it.

4. Adjusting screw

As it is a part of controlling the max. fuel amount if the length which comes outside is long the torque decreases or if the length is short the torque increases.

5. Fuel stop plate

It is the plate which prevents fuel from increasing by stopping the proceeding of adjusting screw.

6. Operating lever

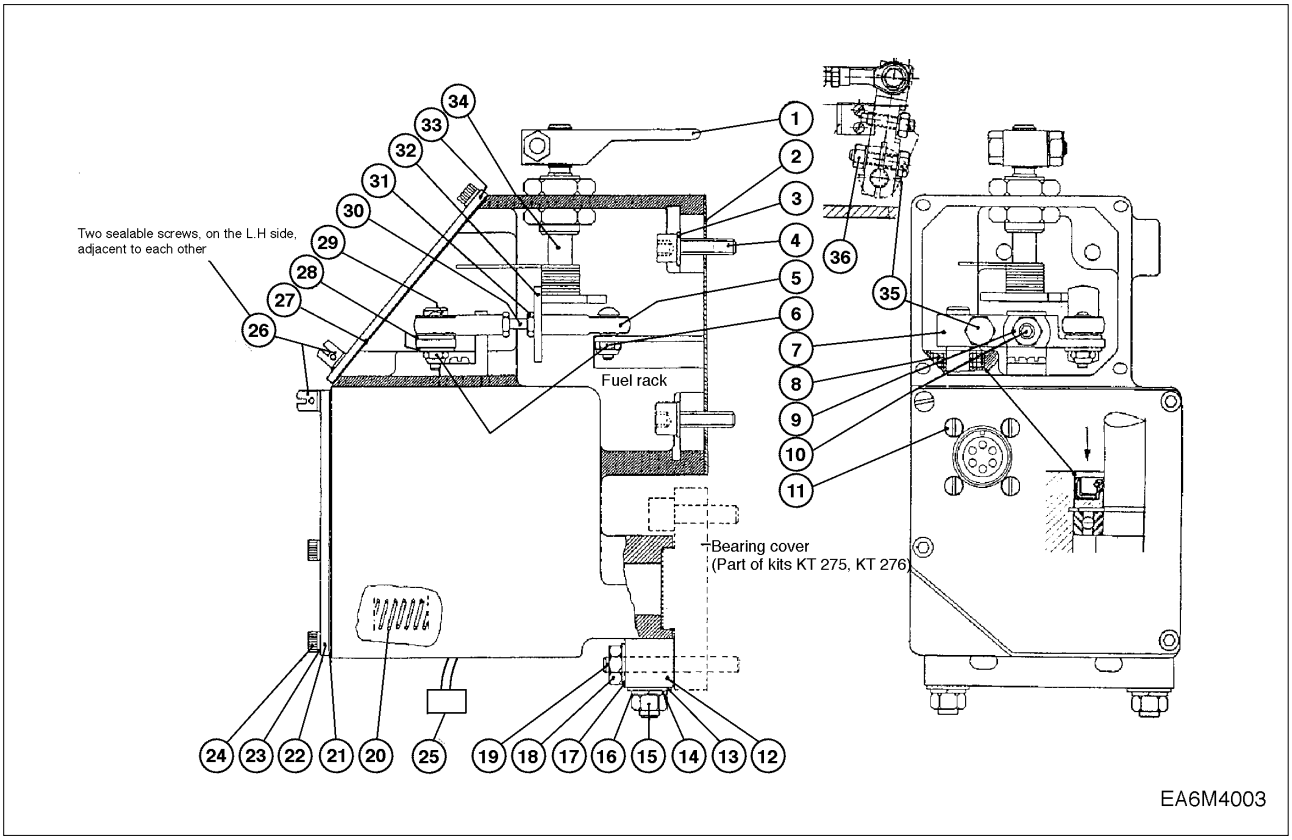
It is a connecting lever for operating the fuel rack.

7. Fuel lever

It is connected with link lever, controls fuel amount of the fuel injection pump.

Caution :

Adjusting the fuel pump is an essential part for performance and endurance of engine, therefore operation and maintenance should be performed only by specialized engineer.



No.	Description	Q'ty	Remark	No.	Description	Q'ty	Remark
1	Stop lever(emergency)	1		20	actuator spring	1	
2	pump gasket	1		21	gasket,lower cover	1	
3	washer	4		22	lower cover	1	
4	allen screw	4	7 ~ 9 N.m	23	washer	8	
5	ball link	2	*	24	allen screw	6	2.0 ± 3.0 N.m
6	stop nut	2	3.5 ~ 4.0 N.m	25	receptacle	1	
7	operating lever	1		26	sealing screw	2	3.5 ± 4.5 N.m
8	oil seal	1		27	gasket, upper cover	1	
9	counter nut	1	4.5 ~ 6.0 N.m	28	flat washer	2	
10	stop screw	1		29	screw, ball link	2	*
11	connector screw	4		30	connecting rod	1	*
12	mounting bar	1		31	nut	2	*
13	flat washer	2		32	stop plate	1	*
14	lock washer	2		33	top cover	1	
15	nut	2	17 ~ 21 N.m	34	manual stop device complete	1	
16	flat washer	2		*	linkage complete comprise pos. 5,6,28,29,30,31,32	1	
17	lock washer	2		35	fixing screw	1	12.5±13.0N.m
18	nut	2	7 ~ 9 N.m	36	stop nut	1	12.5±13.0 N.m
19	threaded bolt (part of bearing kit)	2					

(2) Speed control unit for governor system (All)

a) Introduction

Series speed control unit is an all electronic device designed to control engine speed with fast and precise response to transient load changes. This closed loop control, when connected to a proportional electric actuator and supplied with a magnetic speed sensor signal, will control a wide variety of engines in an isochronous or droop mode.

The speed control unit are the engine **STARTING FUEL** and **SPEED RAMPING** adjustments. The use of these features will minimize engine exhaust smoke experienced prior to attaining engine operating speed.

Other features include adjustable droop and idle operation, inputs for accessories used in multi-engine or special applications, protection against reverse battery voltage, transient voltages, accidental short circuit of the actuator and fail safe design in the event of loss of speed sensor signal or battery supply.

	AD136/T/TI	**AD086TI**
GAC actuator model	ACD 176A-24	ACE 175
Speed control unit model	DWC-2000	ESD55500

b) Description

Engine speed information for the speed control unit is usually received from a magnetic pick-up sensor Any other signal generating device may be used provided the generated frequency is proportional to engine speed and meets the voltage input and frequency range specification. The speed sensor is typically mounted in close proximity to an engine driven ferrous gear, usually the engine ring gear. As the teeth of the gear pass the magnetic sensor, a signal is generated which is proportional to engine speed.

Signal strength must be within the range of the input amplifier. An amplitude of 0.5 to 120 volts RMS is required to allow the unit to function within its design specifications. The speed signal is applied to Terminals C and D of the speed control unit. Between these terminals there is an input impedance of over 33,000 ohms. Terminal D is internally connected to Terminal E, battery negative. Only one end of the cable should be connected.

When a speed sensor signal is received by the controller, the signal is amplified and shaped by an internal circuit to provide an analog speed signal. If the speed sensor monitor does not detect a speed sensor signal, the output circuit of the speed control unit will turn off all current to the actuator.

A summing circuit receives the speed sensor signal along with the speed adjust set point input. The speed range has a ratio of 8:1 and is adjusted with a 25 turn potentiometer. The output from the summing circuit is the input to the dynamic control section of the speed control unit. The dynamic control circuit, of which the gain and stability adjustments are part, has a control function that will provide isochronous and stable performance for most engine types and fuel systems.

The speed control unit circuit is influenced by the gain and stability performance adjustments. The governor system sensitivity is increased with clockwise rotation of the gain adjustment. The gain adjustment has a range of 33:1.

The stability adjustment, when advanced clockwise, increases the time rate of response of the governor system to match the various time constants of a wide variety of engines. The speed control unit is a PID device, the “D”, derivative portion can be varied when required. (See Instability section.)

During the engine cranking cycle, STARTING FUEL can be adjusted from an almost closed, to a nearly full fuel position.

Once the engine has started, the speed control point is determined, first by the IDLE speed set point and the SPEED RAMPING circuit. After engine speed ramping has been completed, the engine will be at its governed operating speed.

At the desired governed engine speed, the actuator will be energized with sufficient current to maintain the desired engine speed, independent of load (isochronous operation).

The output circuit provides switching current at a frequency of about 500Hz to drive the actuator Since the switching frequency is well beyond the natural frequency of the actuator, there is no visible motion of the actuator output shaft.

Switching the output transistors reduces its internal power dissipation for efficient power control. The output circuit can provide current of unto 10amps continuous at 25?C for 12 and 24VDC battery systems. The actuator responds to the average current to position the engine fuel control lever.

In standard operation, the speed control unit performance is isochronous. Droop governing can be selected by connecting terminals K and L and the percent of droop governing can be varied with the droop adjustment control . The droop range can be increased by connecting Terminals G and H.

The speed control unit has several performance and protection features which enhance the governor system. A speed anticipation circuit minimizes speed overshoot on engine start-up or when large increments of load are applied to the engine.

Engine idle speed can be remotely selected and is adjustable. Accessory inputs to achieve variable speed operation and multi-engine control can be accepted by the speed control unit from GAC load sharing modules, automatic synchronizers.

c) Specification

PERFORMANCE		
Isochronous Operation/steady State Stability		± 0.25% or better
Speed Range/Governor		1 K ± 7.5 KHz continuous
Speed Drift with Temperature		± 1% Maximum
Idle Adjust CW		60% of set speed
Idle Adjust CCW		Less than 1,200 Hz.
Droop Range		1 ± 5 % regulation*
Droop Adj. Max. (K-L Jumpered)		400 Hz ± 75 Hz per 1.0 A change
Droop Adj. Min. (K-L Jumpered)		15 Hz ± 6 Hz. per 1.0 A change
Speed Trim Range		± 200 HZ
Remote Variable Speed Range		500 ± 7.5 Hz or any part thereof
Terminal Sensitivity	J	100 Hz ± 15 Hz/Volt @ 5.0 K Impedance
	L	735 Hz ± 60 Hz/Volt @ 65 K Impedance
	N	148 Hz ± 10 Hz/Vo1t @ 1 Meg. Impedance
	P	10 VDC Supply @ 20 ma Max.
Speed switch adjustment range		1,000 ~ 10,000 Hz
ENVIRONMENTAL		
Ambient Operating Temperature Range		- 40 ° to 180 °F (- 40 ° to + 85 °C)
Relative Humidity		up to 95 %
All Surface Finishes		Fungus Proof and Corrosion Resistant
INPUT POWER		
Supply		12 or 24 VDC Battery Systems (Transient and Reverse Voltage Protected)**
Polarity		Negative Ground (Case Isolated)
Power Consumption		50 mA continuous plus actuator current
Actuator Current Range @ 77 ?F (25 ?C) - (Inductive Load)		Min.2.5 Amps/ Max. 10 Amps continuous ***
Speed Sensor Signal		0.5 ~ 120 Volts RMS
Speed switch relay contacts (N.O. and N.C.)		10 Amps
RELIABILITY		
Vibration		1G @ 20 ~ 100 Hz
Testing		100% Functionally Tested
PHYSICAL		
Dimensions		See Outline
Weight		1.8 lbs (820 grams)
Mounting		Any Position, Vertical Preferred

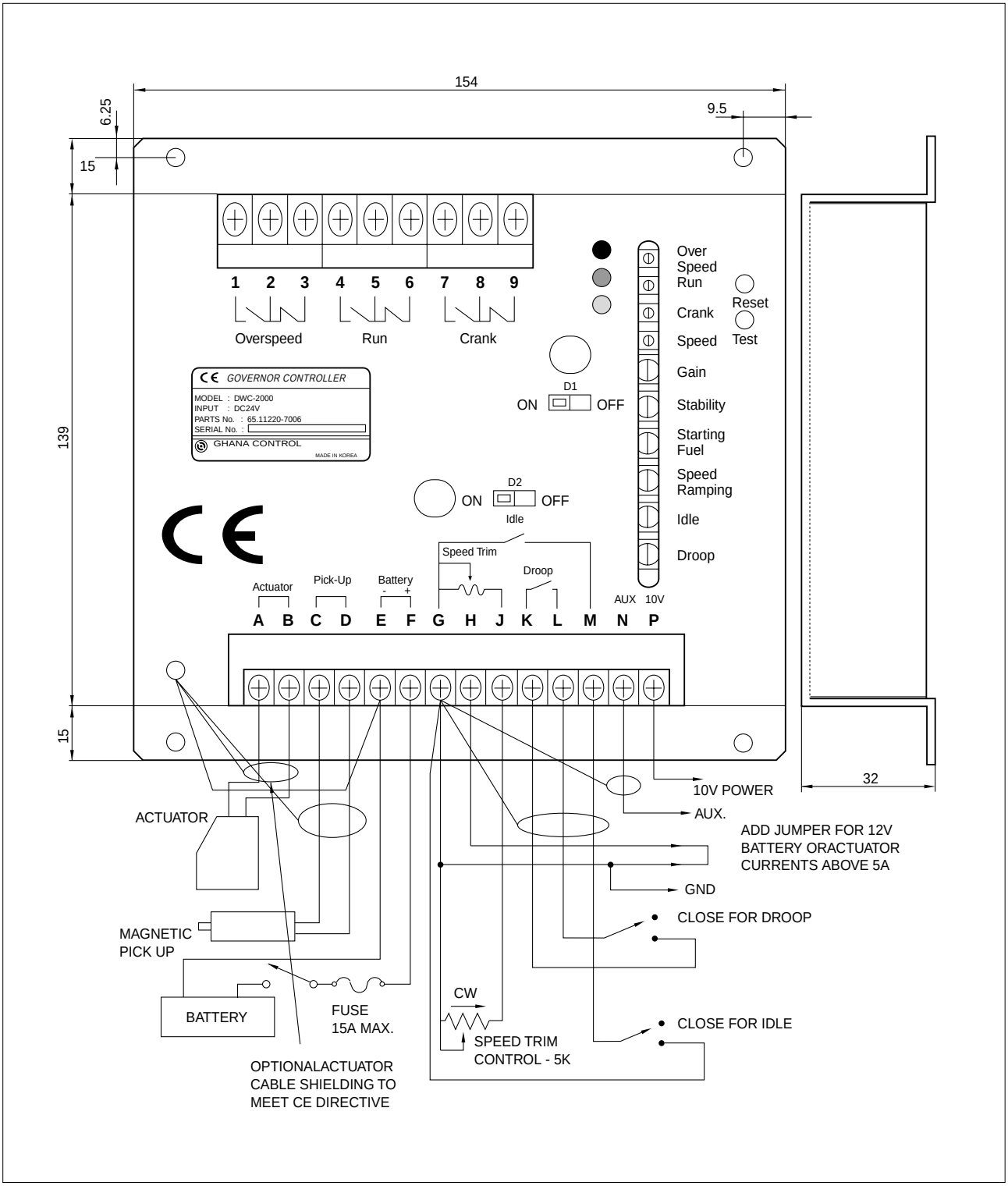
Note :

** Droop is based on a speed sensor frequency of 4,000 Hz and an actuator current. Change of 1 amp from no load to full load. Applications with higher speed sensor signals will experience less percentage of droop. Applications with more actuator current change will experience higher percentages of droop. See droop description for specific details on operation of droop ranges.*

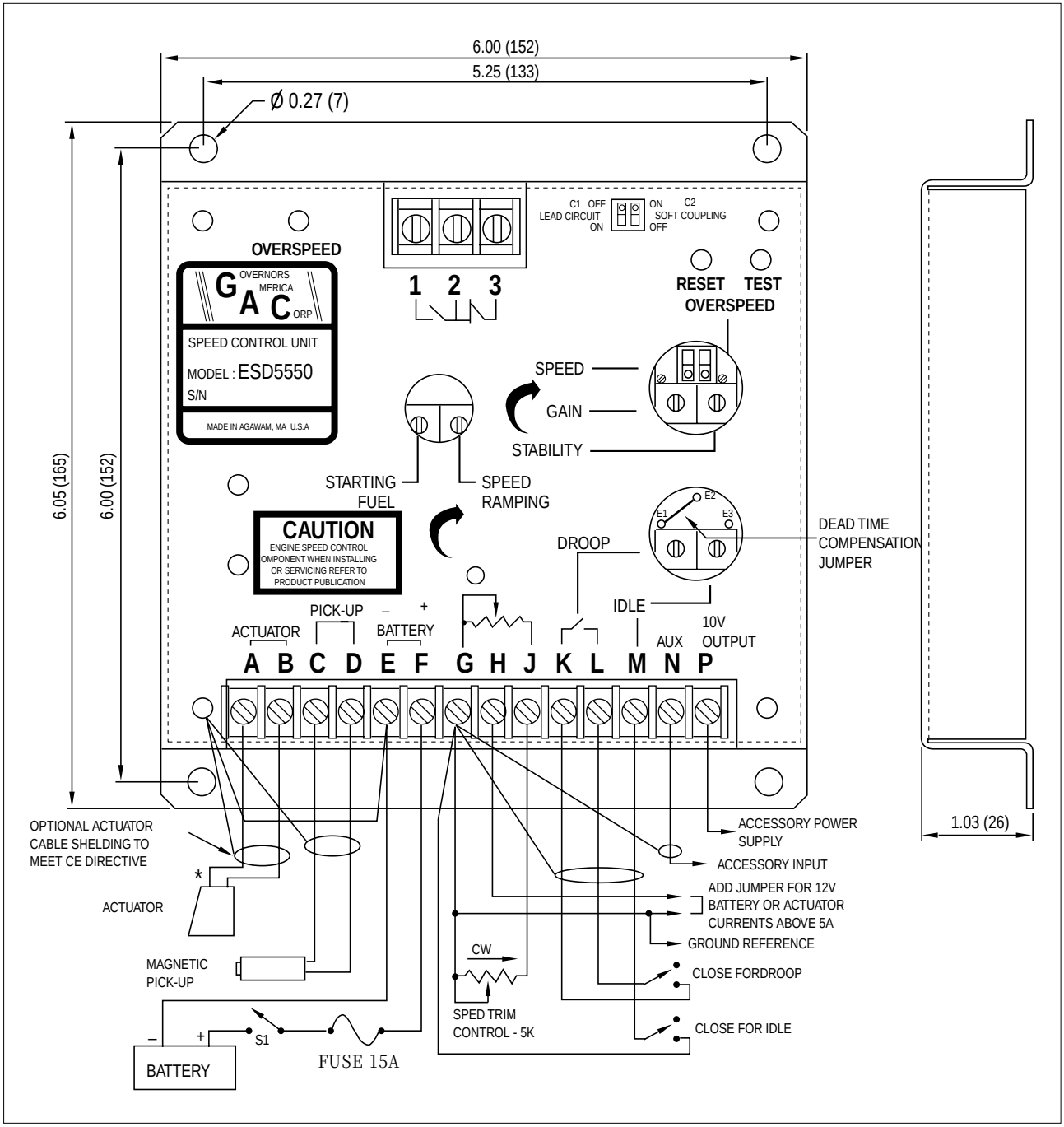
*** Protected against reverse voltage by a series diode. A 15 Amp. fuse must be Installed in the positive battery lead.*

**** Protected against short circuit to actuator (shuts off current to actuator), unit automatically turns back on when shorts is removed.*

d-1) Wiring Diagram and Outline (AD034TI, AD136/T/TI)



d-2) Wiring Diagram and Outline (AD086TI)



Note :

- *If wire leads are longer than 3 meters (10 ft), a shielded cable should be used. Ground shield at one end only.*
- *The speed control unit is rugged enough to be placed in a control cabinet or engine mounted enclosure with other dedicated control equipment. If water, mist, or condensation may come in contact with the controller, it should be mounted vertically. This will allow the fluid to drain away from the speed control unit.*
- *Extremely heat should be avoided.*

Caution :

An overspeed shutdown device, independent of the governor system, should be provided to prevent loss of engine control which may cause personal injury or equipment damage. Do not rely exclusively on the governor system electric actuator to prevent overspeed. A secondary shutoff device, such as a fuel solenoid must be used.

e) Functions of the Control unit

1. STARTING FUEL : When starting engine at first, it controls the amount of starting fuel. If you turn it clockwise, the amount of fuel increases.

2. SPEED RAMPING : It controls time to be taken for the max. speed. If you turn it counter clockwise, the time to be reached the rating speed is reduced.

3. IDLE : Adjust the idle speed of the engine. If the engine rotates clockwise, the speed of the engine increases.

4. GAIN : It makes fluctuant rate of speed which generated from engine stable.

5. STABILITY : It makes fluctuant rate of speed according to the engine mounting stable.

6. SPEED : Adjust the engine speed. If engine rotates clockwise, engine speed increases.

7. OVER SPEED : Adjust engine over speed. If engine rotates clockwise, engine speed increases.

8. DROOP SPEED : It is used in parallel operation of generator.

9. RESET : It is used for initializing the over speed controller.

10. TEST : It is used for confirming and setting the over speed.

11. A, B TERMINAL : They are connected with actuator of the injection pump.

12. C, D TERMINAL : They are connected with magnetic pickup sensor, shield wire should be used. Don't use magnetic pickup sensor connected with them for other purpose.

13. E, F TERMINAL : They are connected with battery (E ⟶ - polar, F⟶ + polar)

14. G,M TERMINAL : They are terminals for maintaining the idle speed.

15. K, L TERMINAL : They are terminals for droop.

16. H, J, N, P TERMINAL : They are subsidiary terminals.

f) Wiring

Basic electrical connections are illustrated above. Actuator and battery connections to Terminals A, B, E, and F should be #16AWG (1.3 mm^2) or larger.

Long cables require an increased wire size to minimize voltage drops.

The battery positive (+) input, Terminal F, should be fused for 15 amps as illustrated.

Magnetic speed sensor connections to Terminals C and D MUST BE TWISTED AND/OR SHIELDED for their entire length. The speed sensor cable shield should only be connected to terminal D. The shield should be insulated to insure no other part of the shield comes in contact with engine ground, otherwise stray speed signals may be introduced to the speed control unit. With the engine stopped,

adjust the gap between the magnetic speed sensor and the ring gear teeth. The gap should not be any smaller than 0.020 in, (0.45 mm). Usually, backing out the speed sensor 3/4 turn after touching the ring gear tooth will achieve a satisfactory air gap. The magnetic speed sensor voltage should be at least 1 VAC RMS during cranking.

g) Adjustments (Used new controller)

1. Before Starting Engine

① The GAIN and STABILITY adjustments are set to mid position.
② STARTING FUEL : FULL CW (Maximum Fuel)
③ SPEED RAMPING : FULL CCW (Fastest)
④ IDLE : FULL CW (Idle speed increase position)
⑤ Place the engine in idle by connecting Terminals M & G.

2. After Starting Engine

When starting engine at first, actuator activates forward “maximum fuel” position. After starting engine, adjust to maintain idle speed. The speed control unit governed speed setting is factory set at approximately engine idle speed. (1000 Hz, speed sensor signal)

① Adjust STARTING FUEL and SPEED RAMPING depending on engine running status.
② If the engine is unstable after starting, turn the GAIN and STABILITY adjustments counterclockwise until the engine is stable.
③ After disconnecting Terminals M & G, turn SPEED to adjust maximum engine speed.
④ After connecting Terminals turn IDLE to set idle speed at 750 rpm. Then disconnect Terminal M & G, to recheck and readjust maximum engine speed.

3. Governor Speeding Setting

The governed speed set point is increased by clockwise rotation of the SPEED adjustment control. Remote speed adjustment can be obtained with an optional 5KΩ Speed Trim Control

4. Governor Performance

Once the engine is at operating speed and at no load, the following governor performance adjustment can be made.

① Rotate the GAIN adjustment clockwise until instability develops.
Gradually move the adjustment counterclockwise until stability returns.
Move the adjustment one division further counterclockwise to insure stable performance.
② Rotate the STABILITY adjustment clockwise until instability develops.
Gradually move the adjustment counterclockwise until stability returns.
Move the adjustment one division further to insure stable performance.
③ Gain and stability adjustments may require minor changes after engine load is applied. Normally, adjustments made at no load achieve satisfactory performance. A strip chart recorder can be used to further optimize the adjustments.

Note :
If instability cannot be corrected or further performance improvements are required, refer to the section on SYSTEM TROUBLESHOOTING.

5. Starting Fuel Adjustment

The engine's exhaust smoke at start-up can be minimized by completing the following adjustments.

① Place the engine in idle by connecting Terminals M & G.

② Adjust the IDLE speed for as low a speed setting as the application allows.

③ Adjust the STARTING FUEL CCW until the engine speed begins to fall, Increase the STARTING FUEL slightly so that the idle speed is returned to the desired level.

④ Stop the engine.

One of two methods of operation for the ESD5550 may now be selected.

Method 1) : Start the engine and accelerate directly to the operating speed (Generator Sets, etc.)

① Remove the connection between Terminals M & G. Start the engine and adjust the SPEED RAMPING for the least smoke on acceleration from idle to rated speed.

② If the starting smoke is excessive, the STARTING FUEL may need to be adjusted slightly CCW. If the starting time is too long, the STARTING FUEL may need to be adjusted slightly CW.

Method 2) : Start the engine and control at an idle speed for a period of time prior to accelerating to the operating speed. This method separates the starting process so that each may be optimized for the lowest smoke emissions.

① Replace the connection between Terminals M & G with a switch, usually an oil pressure switch. Start the engine. If the starting smoke is excessive, the STARTING FUEL may need to be adjusted slightly CCW. If the starting time is too long, the STARTING FUEL may need to be adjusted slightly CW.

② When the switch opens, adjust the SPEED RAMPING for the least amount of smoke when accelerating from idle speed to rated speed.

6. Idle Speed Setting

If the IDLE speed setting was not adjusted as detailed in "Starting Fuel Adjustment" section, then place the optional external selector switch in the IDLE position. The idle speed set point is increased by clockwise rotation of the IDLE adjustment control. When the engine is at idle speed, the speed control unit applies droop to the governor system to insure stable operation.

7. Speed Droop Operation

Droop is typically used for the paralleling of engine driven generators.

Place the optional external selector switch in the DROOP position, DROOP is increased by clockwise rotation of the DROOP adjustment control. When in droop operation, the engine speed will decrease as engine load increases.

The percentage of droop is based on the actuator current change from engine no load to full load. A wide range of droop is available with the internal control. Droop level requirements above 10% are unusual.

If droop levels experienced are higher or lower than those required, contact the factory for assistance.

After the droop level has been adjusted, the rated engine speed setting may need to be reset. Check the engine speed and adjust the speed setting accordingly.

8. Accessory input

The Auxiliary Terminal N accepts input signals from load sharing units, auto synchronizers, and other governor system accessories, accessories are directly connected to this terminal It is recommended that this connection from accessories be shielded as it is a sensitive input terminal. If the auto synchronizer is used alone, not in conjunction with a load sharing module, a 3M ohm resistor should be connected between Terminals N and P This is required to match the voltage levels between the speed control unit and the synchronizer.

When an accessory is connected to Terminal N, the speed will decrease and the speed adjustment must be reset.

When operating in the upper end of the control unit frequency range, a jumper wire or frequency trim control may be required between Terminals G and J. This increases the frequency range of the speed control to over 7000 Hz.

9. Accessory Supply

The +10 volt regulated supply, Terminal P, can be utilized to provide power to governor system accessories. Up to 20mA of current can be drawn from this supply. Ground reference is Terminal G. A short circuit on this terminal can damage the speed control unit.

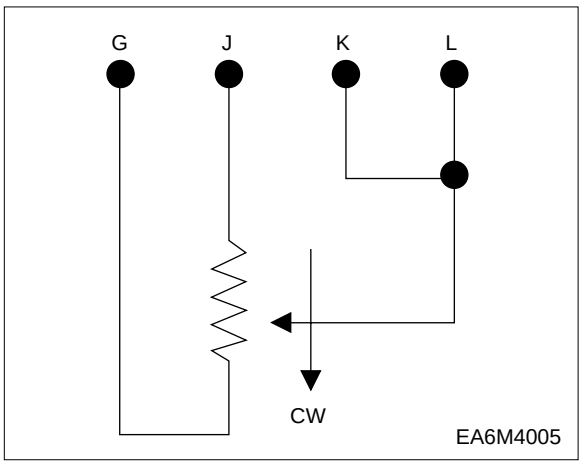
10. Wide Range Remote Variable Speed Operation

A single remote speed adjustment potentiometer can be used to adjust the engine speed continuously over a specific speed range. Select the desired speed range and the corresponding potentiometer value. (Refer to “Speed Range Potentiometer Value”) If the exact range cannot be found, select the next higher range potentiometer. An additional fixed resistor may be placed across the potentiometer to obtain the exact desired range. Connect the speed range potentiometer as shown in the next diagram.

<Speed Range Potentiometer Value>

Speed Range	Potentiometer Value
900 Hz.	1K
2,400 Hz.	5K
3,000 Hz.	10K
3,500 Hz.	25K
3,700 Hz.	50K

* Select Proper Potentiometer Value



Caution :

To maintain engine stability at the minimum speed setting, a small amount of droop can be added using the DROOP adjustment. At the maximum speed setting the governor performance will be near isochronous, regardless of the droop adjustment setting.

Contact the factory for assistance if difficulty is experienced in obtaining the desired variable speed governing performance.

h) System Trouble shooting

1. System Inoperative

If the engine governing system does not function, the fault may be determined by performing the voltage tests described in Steps 1, 2, 3, and 4.Be careful of the meter polarities measuring. Should normal values be indicated as a result of following the trouble shooting steps, the fault may be with the actuator or the wiring to the actuator See the actuator publication for testing details.

STEP	TERMINALS	NORMAL READING	PROBABLE CAUSE OF ABNORMAL READING
1	F(+) & E(-)	Battery supply voltage (12 or 24 VDC)	1. DC battery power not connected. Check for blown fuse 2. Low battery voltage. 3. Wiring error.
2	C & D	1.0 VAC RMS min., while cranking	1. Gap between speed sensor and gear teeth too great. Check gap. 2. Improper or defective wiring to the speed sensor. Resistance between terminals C and D should be 30 to 1,200 ohms. 3. Defective speed sensor.
3	P(+) & G(-)	10 VDC, Internal Supply	1. Short on terminal P (This will cause a defective unit.) 2. Defective Speed Control.
4	F(+) & A(-)	1.0 ~ 2.0 VDC while cranking	1. **SPEED** adjustment set too low 2. Short/open in actuator wiring. 3. Defective speed control. 4. Defective actuator.

2. Unsatisfactory Performance

If the governing system functions poorly, perform the following tests.

SYMPTOM	TEST	PROBABLE FAULT
Engine overspeeds	**1. Do not crank.** Apply DC power to the governor system.	**1.** Actuator goes to full fuel. Then, disconnect speed sensor at Terminals C & D. If actuator still at full fuel speed control unit defective. If actuator at minimum fuel position - erroneous speed signal. Check speed sensor data.
	2. Manually hold the engine at the desired running speed. Measure the DC voltage between Terminals A(-) & F(+) on the speed control unit.	**1.** If the voltage reading is 1.0 to 2.0 VDC. a) **SPEED** adjustment set above desired speed. b) Defective speed control unit.
		2. If the voltage reading is above 2.0 VDC, a) Actuator or linkage binding.
		3. If the voltage reading is below 1.0 VDC, a) Defective speed control unit.
		4. Gain set too low.
Actuator does not energize fully.	**1.** Measure the voltage at the battery while cranking.	**1.** If the voltage is less than 7V for a 12V system, or14V for a 24V system, replace the battery if it is weak or undersized.
	2. Momentarily connect Terminals A and F The actuator should move to the full fuel position.	**1.** Actuator or battery wiring in error.
		2. Actuator or linkage binding.
		3. Defective actuator.
		4. Fuse opens. Check for short in actuator or actuator wiring harness.
Engine remains below desired governed speed.	**1.** Measure the actuator output. Terminals A & B, while running under governor control.	**1.** If voltage measurement is within approximately 2 volts of the battery supply voltage, then fuel control restricted from reaching full fuel position. Possibly due to interference from the mechanical governor, carburetor spring or linkage alignment.
		2. Speed setting too low.

3. Insufficient Magnetic speed Sensor Signal

A strong magnetic speed sensor signal will eliminate the possibility of missed or extra pulses. The speed control unit will govern well with 0.5volts RMS speed sensor signal. A speed sensor signal of 3volts RMS or greater at governed speed is recommended. Measurement of the signal is made at Terminals C and D.

4. Electromagnetic Compatibility (EMC)

The governor system can be adversely affected by large interfering signals that are conducted through the cabling or through direct radiation into the control circuits.

All speed control units contain filters and shielding designed to protect the units sensitive circuits from moderate external interfering sources.

Although it is difficult to predict levels of interference, applications that include magnetos, solid state ignition systems, radio transmitters, voltage regulators or battery chargers should be considered suspect as possible interfering sort traces.

If it is suspected that external fields, either those that are radiated or conducted, are or will affect the governor systems operation, it is recommended to use shielded cable for all external connections.

Be sure that only one end of the shields, including the speed sensor shield, Is connected to a single point on the case of the speed control unit. Mount the speed control unit to a grounded metal back plate or place it in a sealed metal box.

Radiation is when the interfering signal is radiated directly through space to the governing system To isolate the governor system electronics from this type of interference sort roe, a metal shield or a solid metal container is usually effective.

Conduction is when the interfering signal is conducted through the interconnecting wiring to the governor system electronics. Shielded cables and installing filters are common remedies.

As an aid to help reduce the levels of EMI of a conductive nature, a battery line filter and shielded cables are conveniently supplied by KT130. To reduce the levels of EMI of a radiated nature, a shielded container P/N CA114 can be sourced from GAC and its distributors.

In severe high energy interference locations such as when the governor system is directly in the field of a powerful transmitting source, the shielding may require to be a special EMI class shielding. For these conditions, contact GAC application engineering for specific recommendations.

5. Instability

Instability in a closed loop speed control system can be categorized into two general types.

① PERIODIC appears to be sinusoidal and at a regular rate.

② NON-PERIODIC is a random wandering or an occasional deviation from a steady state band for no apparent reason

Switch C1 controls the “Lead Circuit” found. The normal position is “ON “ Move the switch to the “OFF” position if there is fast instability in the system.

Switch C2 controls an additional circuit added is designed to eliminate fast erratic governor behavior, caused by very soft or worn couplings in the drive train between the engine and generator.

The normal position is “OFF”. Move to the “ON” position if fast erratic engine behavior due to a soft coupling is experienced.

The PERIODIC type can be further classified as fast or slow instability. Fast instability is a 3Hz. or faster irregularity of the speed and is usually a jitter Slow periodic instability is below 3Hz., can be very slow, and is sometimes violent.

If fast instability occurs, this is typically the governor responding to engine firings.

Raising the engine speed increases the frequency of Instability and vice versa.

In this case, placing switch C1 in the “OFF” position will reduce the speed control unit’s sensitivity to high frequency signals.

Readjust the GAIN and STABILITY for optimum control Should instability still be present, the removal of E1 to E2 jumper may help stabilize the engine. Post locations are illustrated. Again, readjust the GAIN and STABILITY for optimum control. Interference from powerful electrical signals can also be the cause. Turn off the battery chargers or other electrical equipment to see if the system disappears.

Slow instability can have many causes. Adjustment of the GAIN and STABILITY usually cures most situations by matching the speed control unit dynamics. If this is unsuccessful, the dead time compensation can be modified. Add a capacitor from posts E2 to E3 (negative on E2). Post locations are illustrated. Start with 10mfds. and increase until instability is eliminated. The control system can also

be optimized for best performance by following this procedure.

If slow instability is unaffected by this procedure, evaluate the fuel system and engine performance. Check the fuel system linkage for binding, high friction, or poor linkage. Be sure to check linkage during engine operation. Also look at the

engine fuel system. Irregularities with carburetion or fuel injection systems can change engine power with a constant throttle setting Th is can result in speed deviations beyond the control of the governor system. Adding a small amount of droop can help stabilize the system for troubleshooting.

NON-PERIODIC instability should respond to the GAIN control. If increasing the gain reduces the instability, then the problem is probably with the engine. Higher gain allows the governor to respond faster and correct for disturbance. Look for engine misfirings, an erratic fuel system, or load changes on the engine generator set voltage regulator If the throttle is slightly erratic, but performance is fast, move switch C1 to the “OFF” position. This will tend to steady the system.

If unsuccessful in solving Instability, contact the factory for assistance.

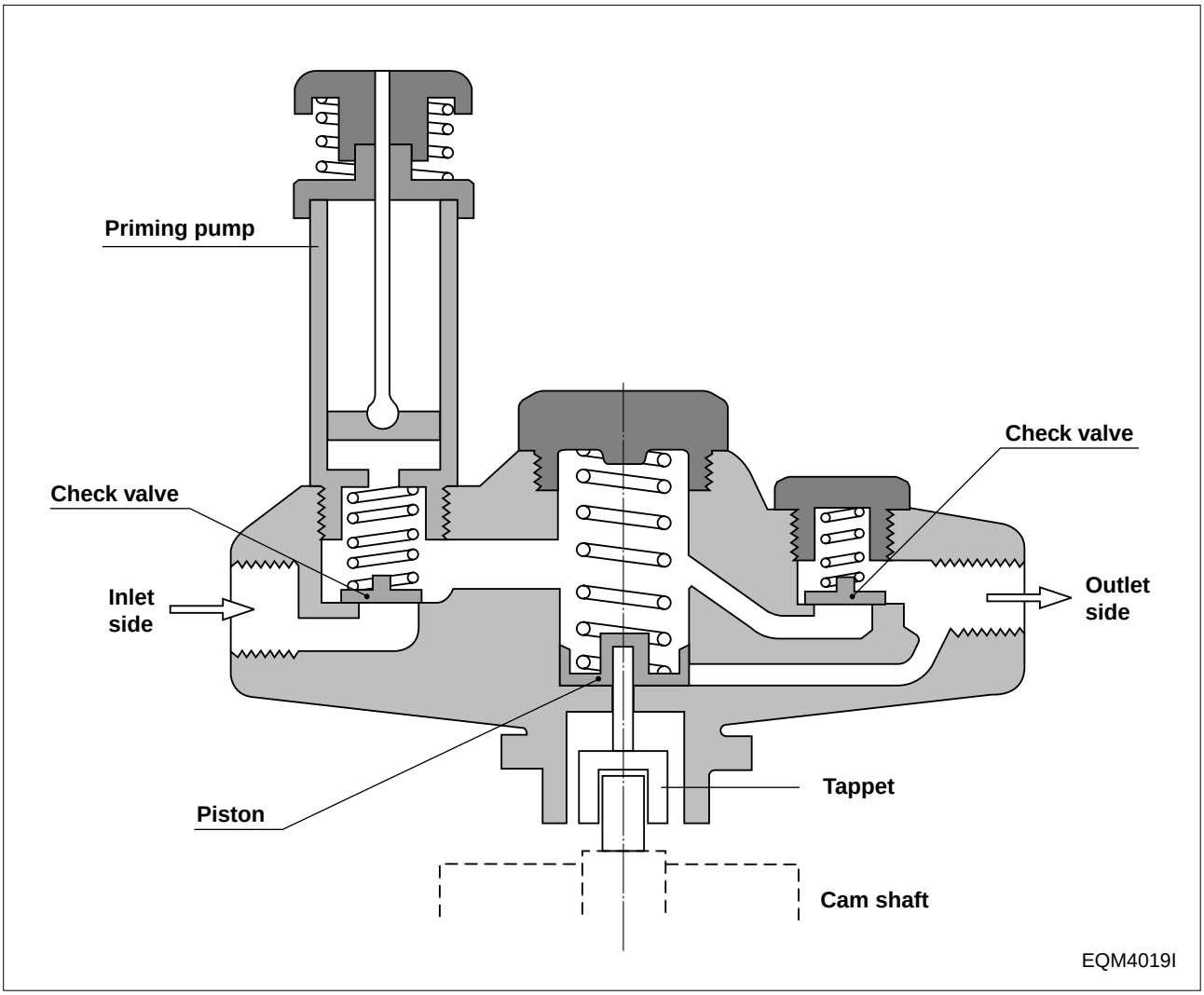
7.3.3. Fuel feed pump

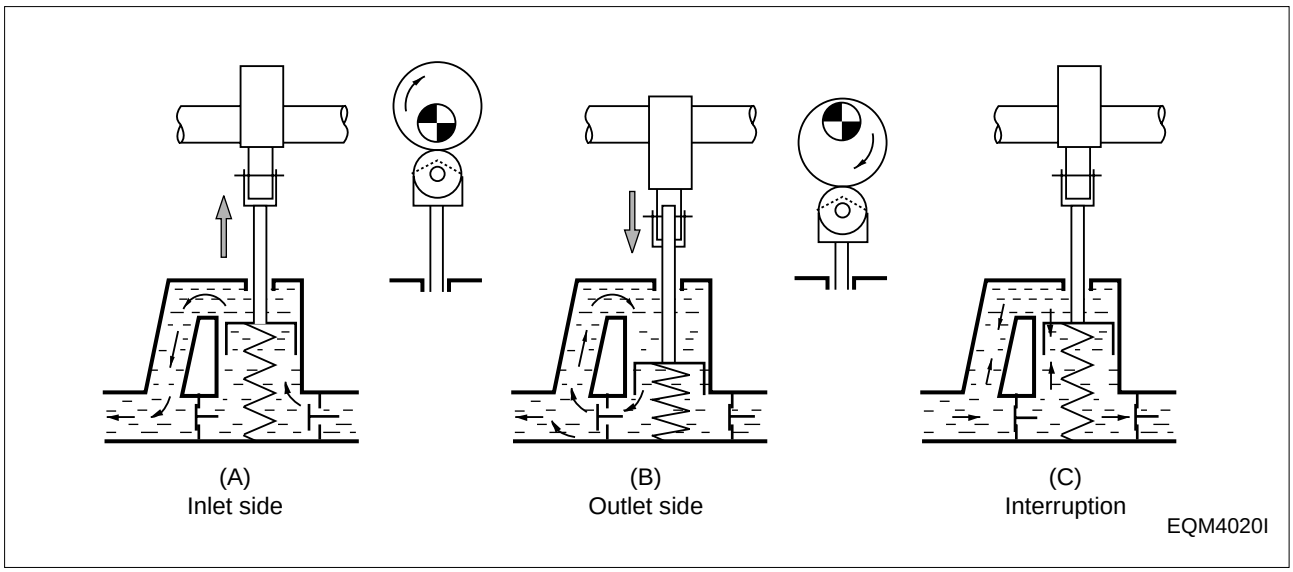
1) General descriptions and construction

The P-type injection pump is mounted with NP-FP or KD-PS type feed pump. These pumps have the same basic construction and operation, and the general descriptions of the KD type pump are given below:

The figures show its construction (right figure) and operation (below figure). The piston in the fuel feed pump is driven by the push rod and tappet via the camshaft of injection pump and performs reciprocating operation to control the suction and delivery of fuel. When the cam reaches the Bottom Dead Center as shown in the figure, the fuel is drawn in through the check valve on the inlet side.

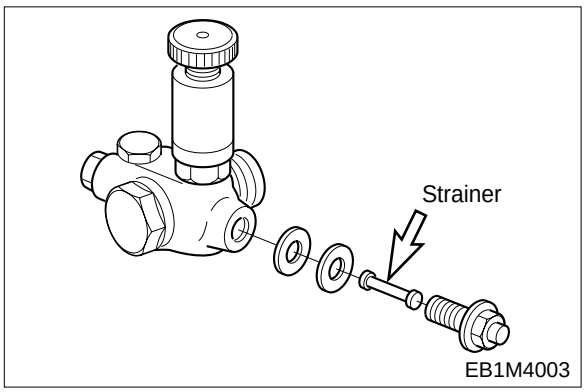
The fuel pressurized as the cam rotates on flows through the check valve on the outlet side as shown in (B). If the feeding pressure increases abnormally, the spring is compressed, resulting in interrupting further delivery of fuel as shown in (C).



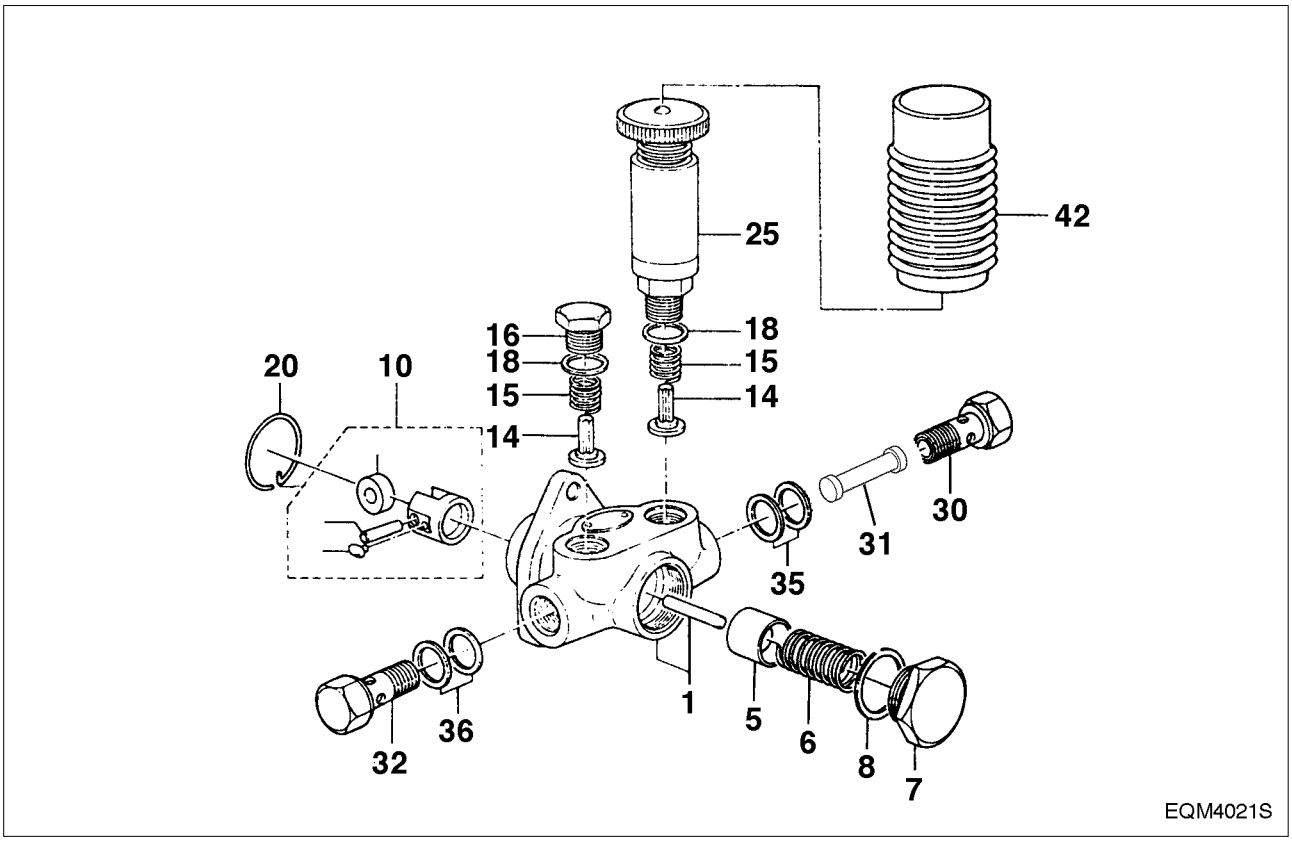


This feed pump is mounted with a priming pump designed to permit manual feeding of fuel from the fuel tank with the injection pump mounted in the engine. During the manual feeding operation, air must be bled from the fuel lines.
When using the priming pump, fix it securely to prevent the possible entry of moisture or other foreign substances in the inside of feed pump.

In addition, a strainer is fitted into joint bolt on the inlet side of the fuel feed pump to filtrate any foreign substances possibly mixed in fuel.



2) disassembly



- Clamp the feed pump with a vise and disassemble the plugs (30, 32), strainer (31) and gaskets (35, 36).
- Take off the priming pump (25), plug (16), both gaskets (18), spring (15), and check valve (14).
- Take off the plug (7), gasket (8), spring (6), and piston (5) on the piston side.
- Pull out the snap ring (20) holding the tappet (10).
- Disassemble the snap ring, then take off the tappet (10) and push rod (1).

3) Inspection

- If the check valve is damaged or scored on its seat face, replace it with a new one.
- Inspect the piston and tappet for damage.
- Replace the push rod if excessively worn, and replace together with the pump housing if required. The inspection for wear should be performed in the same procedure as for suction pressure test described below.

4) Re-assembly

- Re-assembly operation is performed in reverse order of disassembly. All the gaskets must be replaced with new ones at re-assembly.

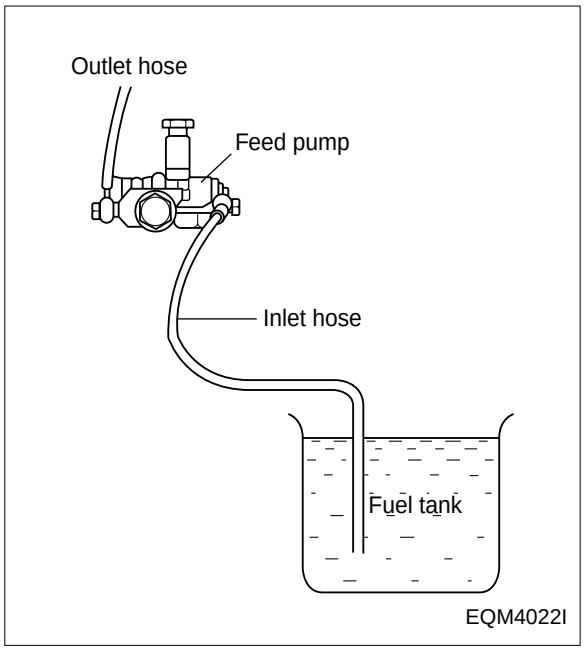
5) Testing

(1) Suction capacity test

Connect one end of a hose to the inlet side of the feed pump and immerse the other end of it into the fuel tank as illustrated.

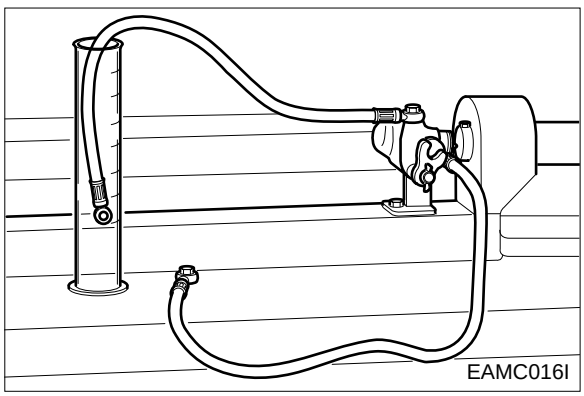
Hold the feed pump in position about 1 m above the level of fuel in the fuel tank.

Operate the tappet at the rate of 100 rpm and check to see if fuel is drawn in and delivered for 40 seconds or so.



(2) Delivery test

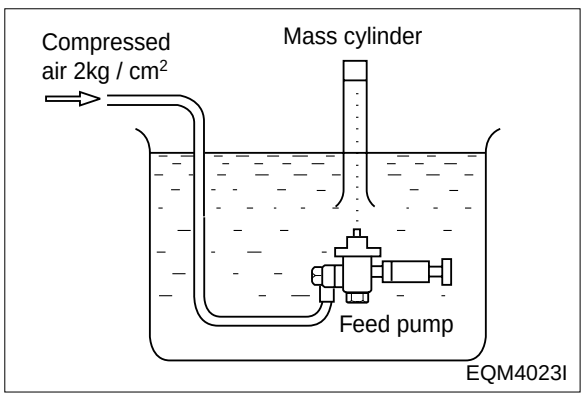
Make a test with the feed pump mounted on a pump tester as illustrated. Operate the pump at the rate of 1,000 rpm and check to see if the pump delivery is more than 405 cc/15 seconds.



(3) Sealing test

Plug up the delivery port on the feed pump and apply compressed air of 2 kg/cm^2 into the inlet side.

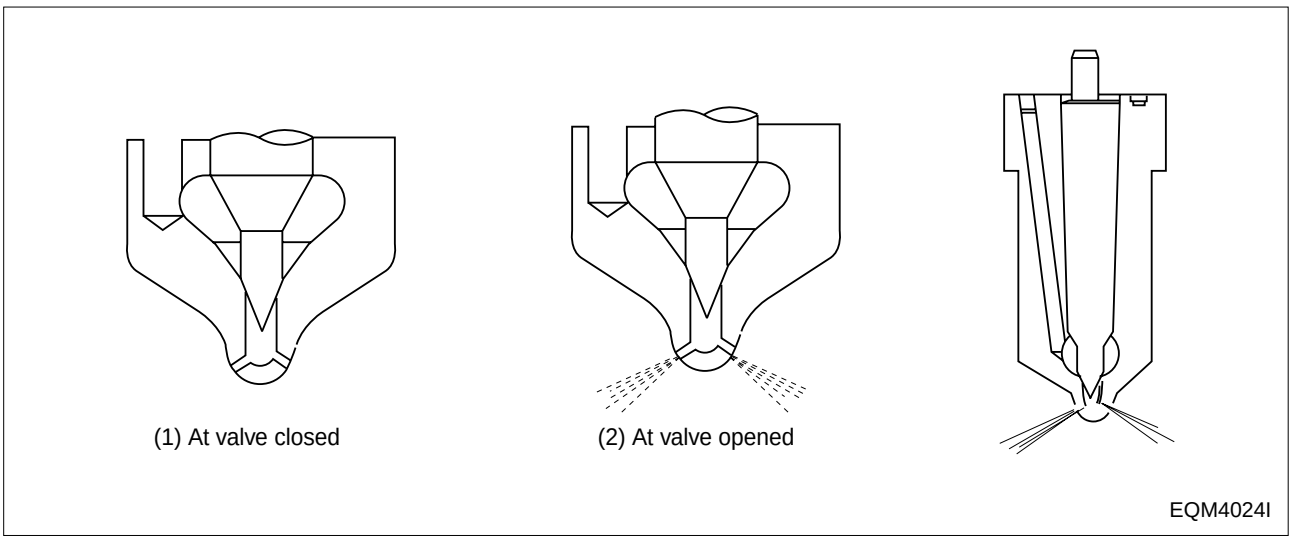
Submerge the feed pump in a container of diesel fuel and check for air leak.



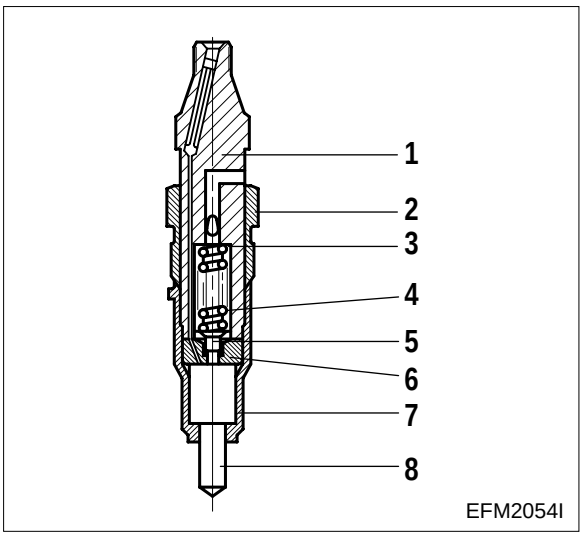
7.3.4. Fuel injection nozzle

The injection nozzle assembly consists of the nozzle body and needle valve assembly. Pressurized fuel delivered from the fuel injection pump is sprayed into the combustion chamber past the injection nozzle at proper spray pressure and spray angle, then burnt completely to achieve effective engine performance.

The fuel injected should necessarily be ignited immediately and combusted in a short period of time as too long a combustion period will prevent the high speed operation of the engine and can cause serious engine knocking.



1) Construction



1. Nozzle holder
2. Union nut
3. Shim
4. Coil spring
5. Guide bush
6. Intermediate washer
7. Nozzle nut
8. Nozzle

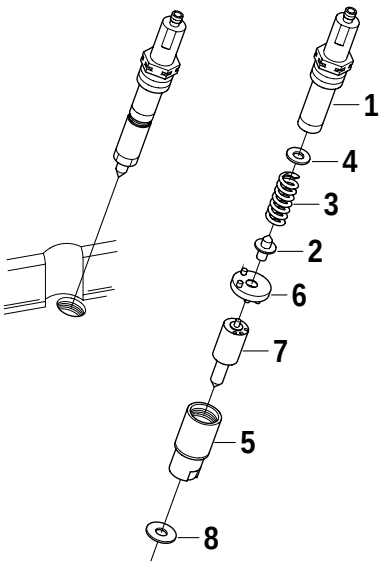
2) Maintenance

Exercise extreme care when handling the injection nozzle assembly, particularly nozzle body and needle valve as these parts are ultra precisely finished.

Wash clean the injection nozzle and remove it from the engine prior to disassembling.

(1) Disassembly

- Clamp the nozzle holder in a vise and remove the cap nut.
- Loosen the adjust screw lock nut and remove the adjust screw then detach the spring and push-rod
- Clamp the nozzle holder body with the nozzle side up in a vise.
- With a wrench remove the nozzle nut using care not to drop the nozzle. Remove the nozzle carefully not to drop the needle valve.



1. Nozzle Holder
2. Guide bush
3. Coil spring
4. Shim
5. Union nut
6. Intermediate washer
7. Nozzle
8. Seal ring

EB1M4004

- **Visual inspection**

After washing, check the injection nozzles against the following:

(1) Needle valves

Check the valve seats, guide shafts and injection shaft for damage.

(2) Nozzle body

Check the valve seats for carbon deposit and damage. Also check the injection orifices for uneven wear.

Replace both of the parts by using assembly even if either of the needle valve or the nozzle body is found to be defective.

- **Sliding test**

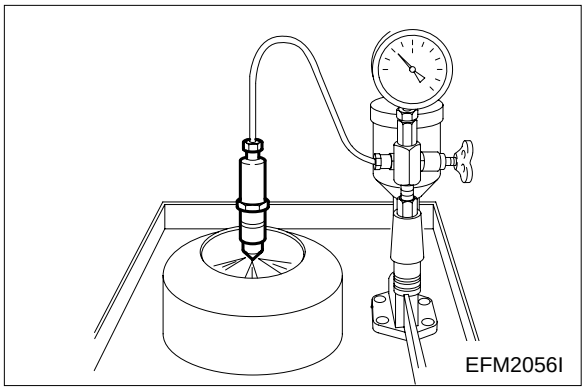
A sliding test should be made on the entire injection nozzle often visual inspection.

Hold the nozzle body vertically and pull the needle valve upward about 1/3 of its entire length and release it and see if it lowers onto its seat by its own weight.

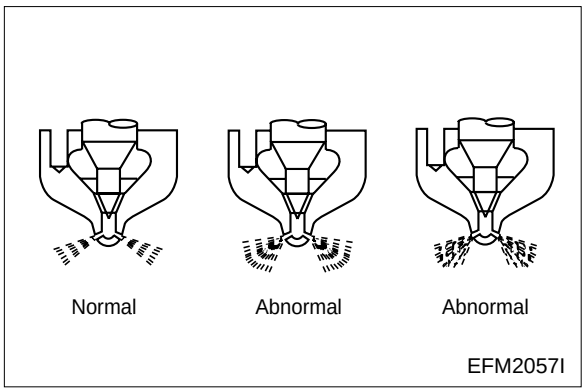
If lowering of the needle valve is not smooth, check for presence of foreign matter and repeat the test. If the trouble persists, replace the entire nozzle assembly with a new one.

(2) Adjustment

- Remove the cap nut and assemble a nozzle to a nozzle tester.
- With the adjusting screw loosened, operate the nozzle 2 ~ 3 times to bleed it.
- Operate the nozzle tester lever at the specified rate.
- Adjust the injection pressure to the standard pressure using the adjusting screw.



- After adjusting the injection pressure, tighten the cap nut to specified torque.
- Re-check the injection pressure and see if the spray pattern is normal. Spray pattern should be uniform and free of spattering.

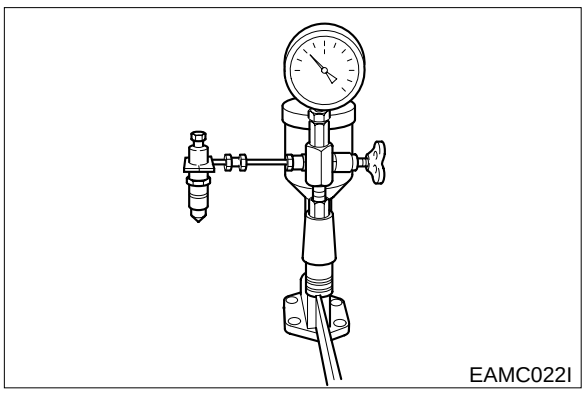


(3) Testing

With the nozzle assembled to a nozzle tester and specified pressure applied, check the nozzle for fuel leakage.

Model	L136/T/TI/086TI
Opening pressure	214 + 8 kg/cm^2

If the joints are free from leaks and the needle valve is working normally, the operation of the nozzle will be accompanied by whistling sound.
Adjust the standard pressure by means of the spring adjusting screw.



(4) Re-assembly

- After removing carbon deposit, submerge the nozzle in diesel oil and clean it.
- Replace all the gaskets with new ones.
- Assemble the parts and tighten them to specified torque.

Items	Torque (kg·m)
Nozzle holder cap nut	7
Nozzle cap nut	6 ~ 8
Injection pipe cap nut	2.9 ~ 3.2
Injection pump delivery valve holder	2.5 ~ 3.0

7.4. Turbocharger

The turbocharger is a system designed to make use of the engine exhaust gas energy to charge high-density compressed air into the cylinders, thereby to increase the engine output. As explained, the compressing of air to supply into the cylinders is called “Supercharging” and the making use of the energy of exhaust gas discharged from the combustion chamber to charge the compressed air into the cylinders is called “Turbocharging”.

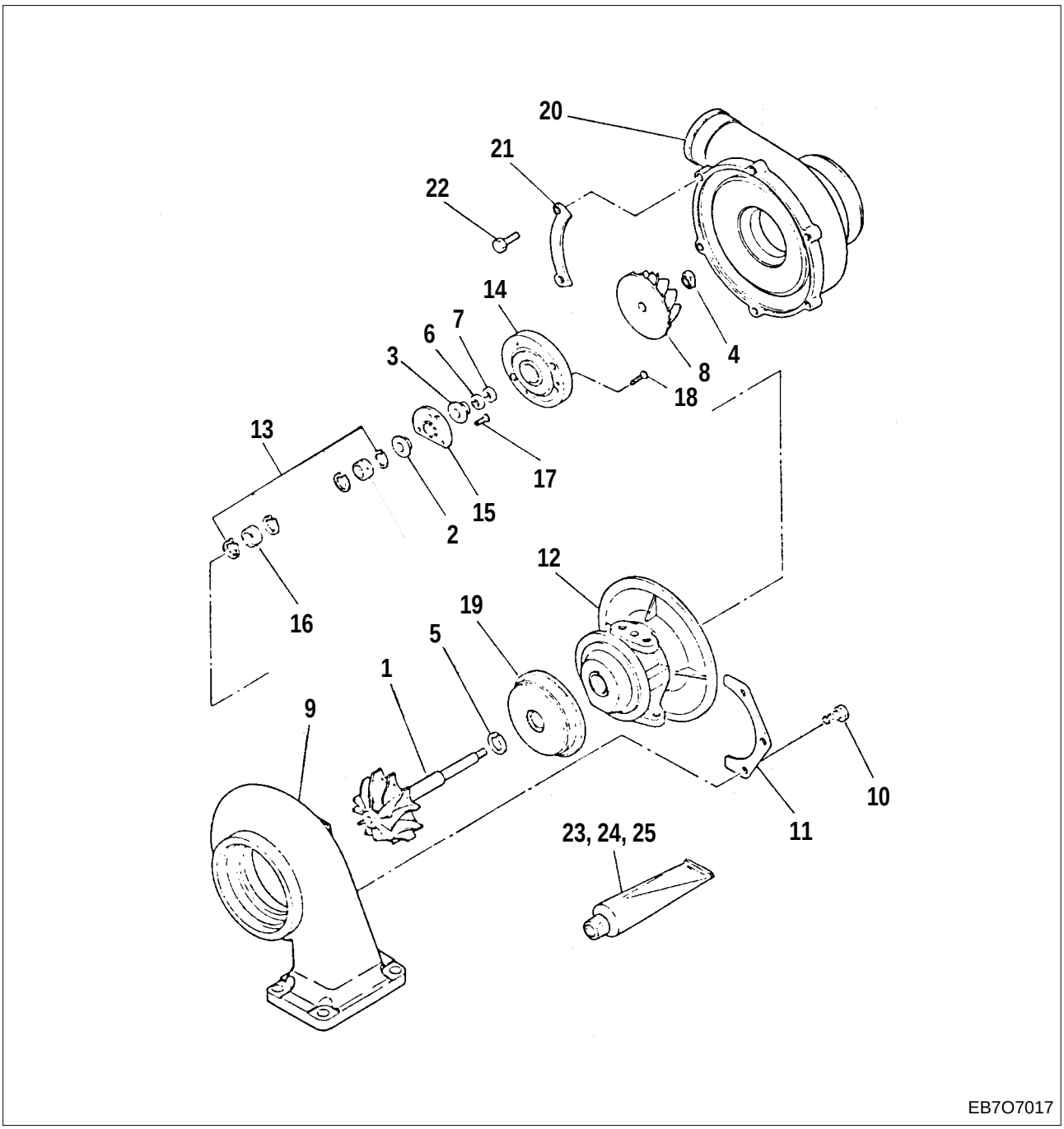
7.4.1. Specification

1) Main data and specifications

Sepecification		L136T/TI	L086TIH	L086TIM
Turbocharger Model		T04E55	HX35	
At maximum output	Air pressure at compressor	About 1.2 kg/cm^2	About 1.24 kg/cm^2	About 1.44 kg/cm^2
	Air suction volume	About 19.0 m^3/min	About 15.4 m^3/min	About 18.6 m^3/min
	Speed of turbine revolution	About 100,000 rpm	About 83,000 rpm	About 83,000 rpm
Maximum allowable speed		130,000 rpm	130,000 rpm	
Max. allowable temperature of exhaust gas at turbine inlet		750°C	700°C	
Lubricating system		→	External oil supply	
Weight		10 kg	21 kg	

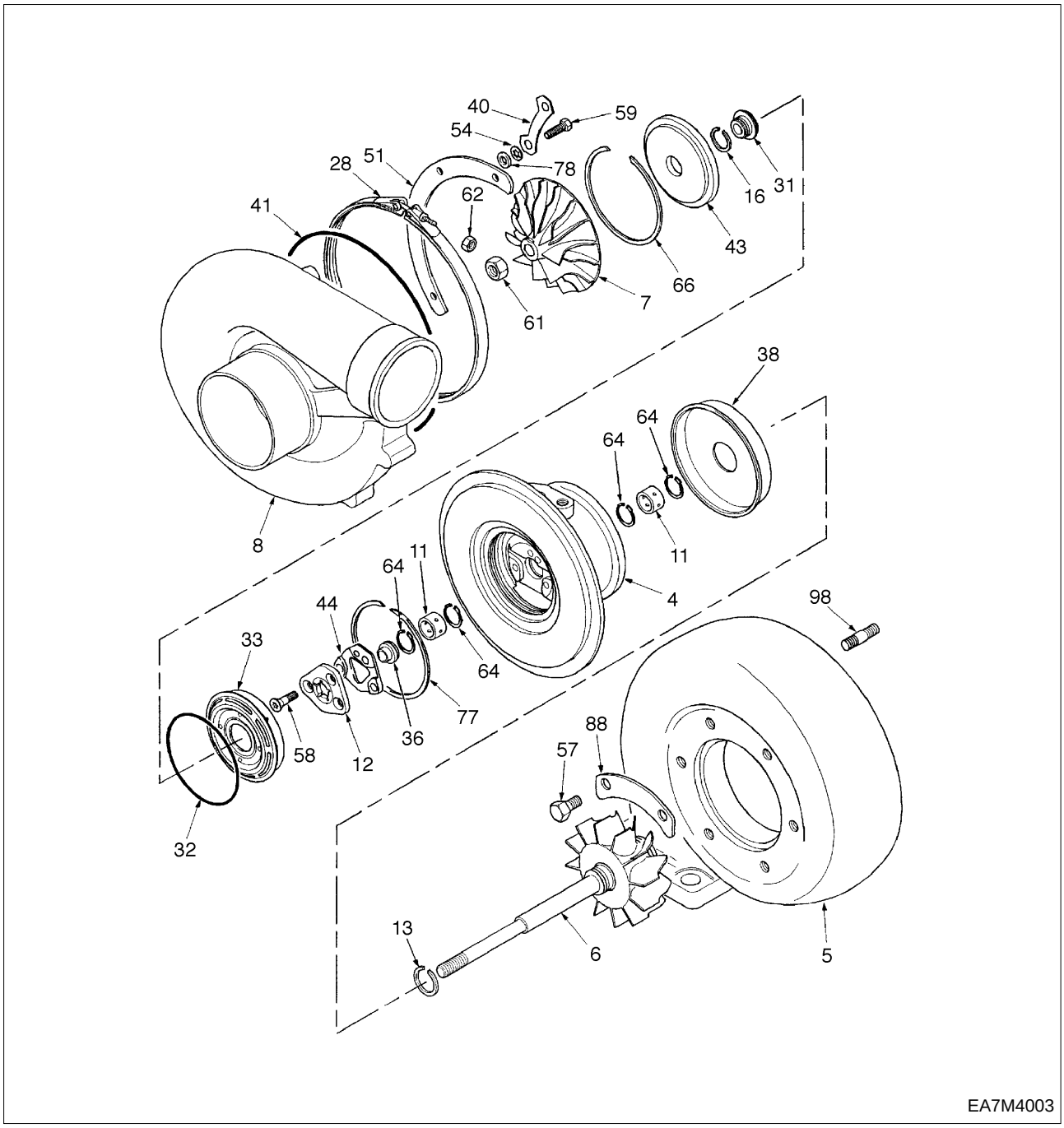
7.4.2. Turbo charger assembly

1) L136T / TI : TO4E55



1. Turbine Shaft
2. Thrust Bush
3. Oil Shut Off
4. Lock Nut
5. Seal Ring
6. Seal Ring
7. Seal Ring
8. Compressor Seal
9. Turbine Housing
10. Bolt
11. Clamp
12. Bearing Housing
13. Retainer Ring
14. Seal Plate
15. Thrust Bearing
16. Journal Bearing
17. Screw
18. Screw
19. Heat Plate
20. Compressor Housing
21. Clamp
22. Bolt
23. Liquid Gasket
24. Loctite
25. Liquid Anti-Burn Agent

2) L086TI (HX35)



2. Center housing rotating assembly
4. Bearing Housing
5. Turbine housing
6. Assembly turbine wheel
7. Compressor wheel
8. Compressor housing
11. Journal bearing
12. Thrust bearing
13. Piston ring seal, turbine
16. Piston ring seal, compressor
29. V-band clamp
31. Oil slinger
32. O ring seal, bearing housing
33. Oil baffle
36. Thrust collar
38. Heat shield
40. Lock plate compressor
41. O ring seal, compressor
43. Oil seal plate
44. Thrust bearing spacer
51. Clamp plate, compressor cover
54. Lock washer, compressor
57. Bolt, turbine housing
58. Screw thrust bearing
59. Bolt compressor cover
61. Lock nut, compressor wheel
62. V-band lock nut
64. Ring retainer bearing
66. Insert, retaining ring
77. Flat retaining ring
78. Washer, compressor
88. Clamp plate, turbine

7.4.3. Inspection

As the condition of turbocharger depends greatly on how well the engine is serviced, it is very important to maintain the engine in accordance with the specified maintenance procedure and pay particular attention to checking oil & air leaks, unusual sound on running.

1) Checking of the rotor for rotating condition

The inspection of the rotor assembly for rotating condition should be performed by the degree of unusual sound on running. If a sound detecting bar is used, install its tip on the turbocharger housing and increase the engine revolutions slowly. If a high-pitch sound is heard every 2~3 seconds or continuously , it means that the rotor assembly is not normal. In this case, as the metal bearing and rotor are likely to be in abnormal conditions, the turbocharger should be replaced or repaired.

2) Checking of the rotor end play

The radial and axial clearances of the rotor should check after every 2,000 hours operation. This precaution will enable measuring for any wear of axial clearance bearings to be detected in good time before serious damage is caused to the rotor and bearings.

Disassemble the turbocharger from the engine, then check the rotor axial play and radial play.

(1) When disassembling the turbocharger, be sure to plug the oil inlet and outlet ports

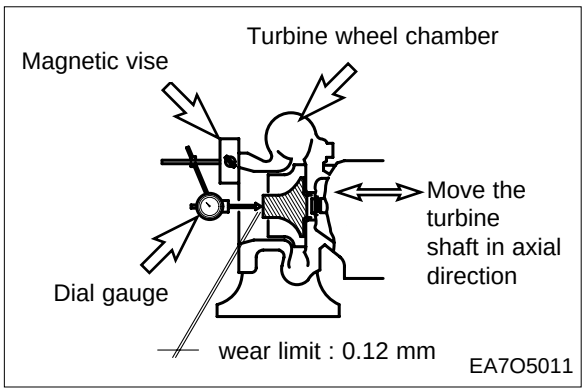
(2) If the measured axial and radial plays are beyond the limit of wear, replace or repair the turbocharger.

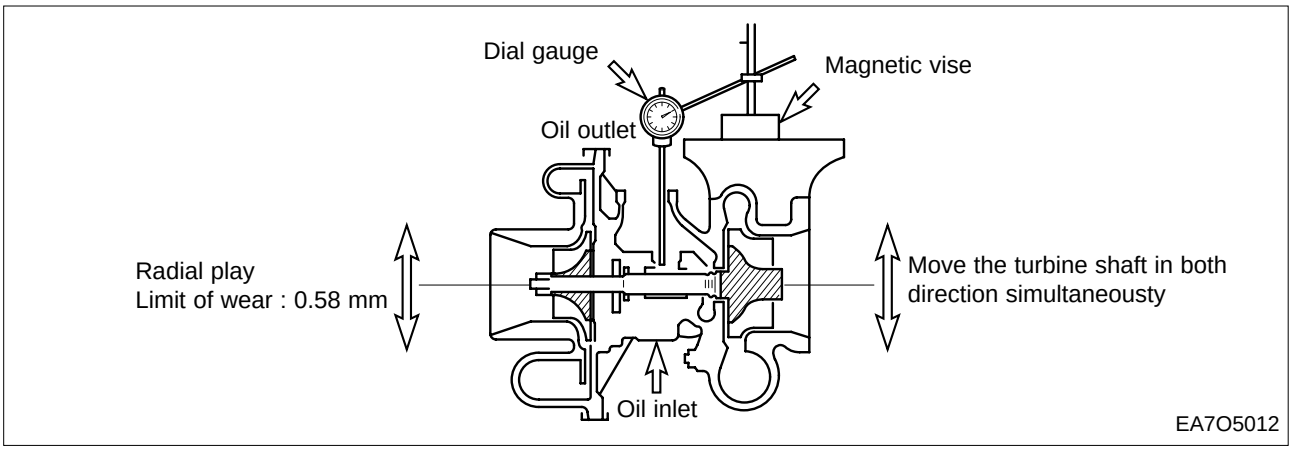
- **Measuring rotor axial clearance**

Radial clearance	0.12 mm

- **Measuring radial clearance**

Radial clearance	0.58 mm





3) Precautions for reassembling the turbocharger onto the engine

For re-assembly of the turbocharger or handling it after re-assembly operation, be sure to observe the following precautions : Especially, pay attention to prevent foreign matters from entering the inside of the turbocharger.

(1) Lubricating system

- Before reassembling the turbocharger onto the engine, inject new oil in the oil inlet port and lubricate the journal and thrust bearings by rotating them with hand.
- Clean not only the pipes installed between the engine and oil inlet port but also the oil outlet pipe and check them for damage or foreign matters.
- Assemble each joint on oil pipes securely to prevent oil leaks.

(2) Intake system

- Check the inside of the intake system for foreign matters.
- Assemble each joint on the intake duct and air cleaner securely to prevent air leaks.

(3) Exhaust system

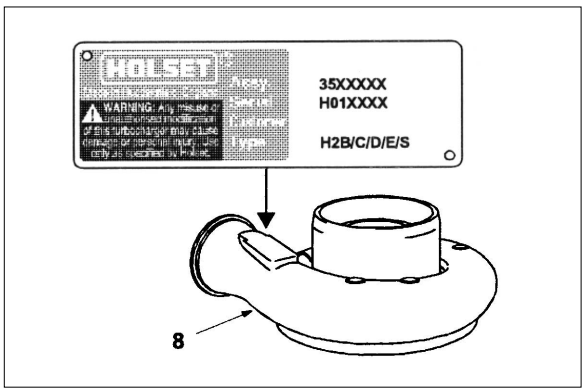
- Check the inside of the exhaust system for foreign matters.
- Be sure to use heat resisting steel bolts and nuts. Do not interchange them with ordinary steel bolts and nuts when performing re-assembly operation. Apply anti-seizure coating to the bolts and nuts.
- Assemble each joint on the exhaust pipes securely to prevent gas leaks.

7.4.4. Maintenance

1) Component identification

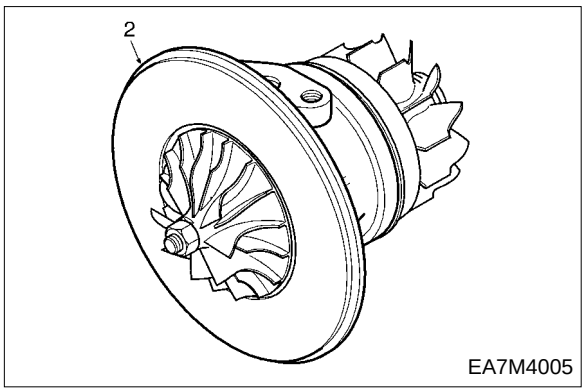
- **Turbocharge identification**

  A dateplate is fitted to the compressor housing (8). The information on this dateplate must be quoted for service and parts support.



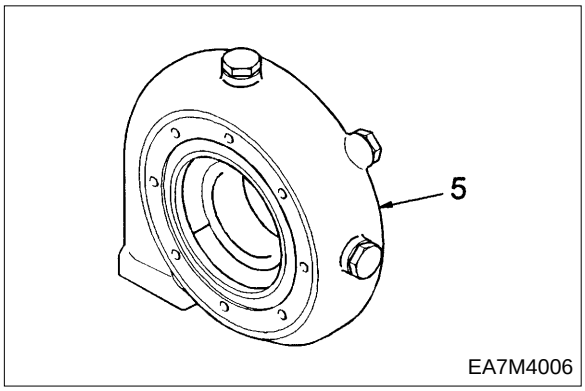
EA7M4004

- **Center housing rotating assembly (H2D)**



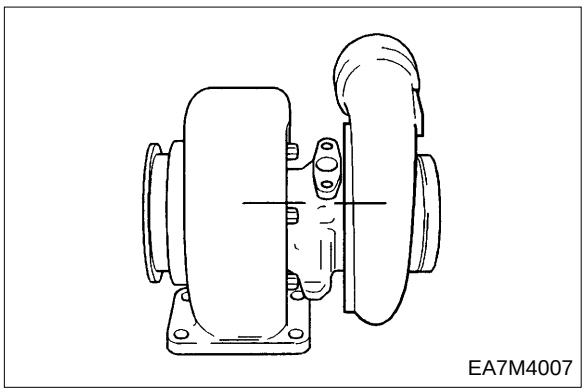
- **Watercooled bearing housing (5)**

  This can have additional water feed drain plug fittings. Special attention should be made to the position of these fittings as this may be specific for each application.



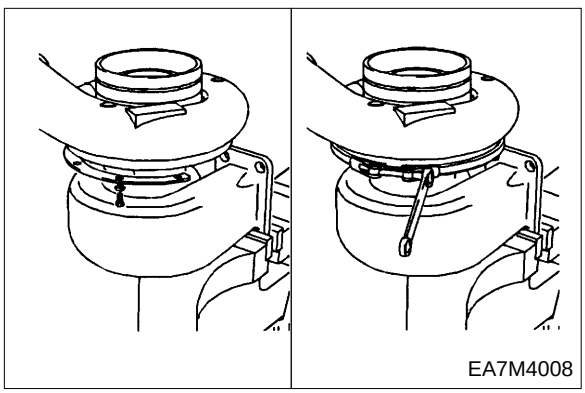
2) Disassembly

- Before disassembling the turbocharger, scribe the parts listed below to help in alignment during assembly.

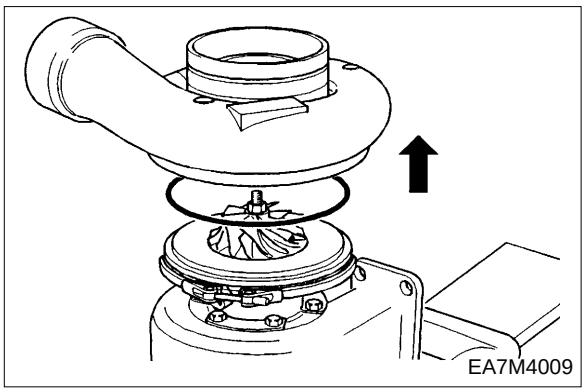


- Secure the turbine housing (5) in a vice. Loosen and remove the 8 bolts (59) lock washers (54) clamp plates (51).

  Loosen and remove the compressor side V-band lock nut (62).

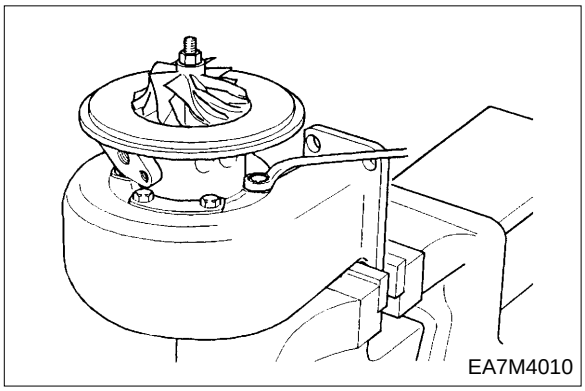


- Gently remove the compressor cover (8), and fitted, remove the O ring seal (41).

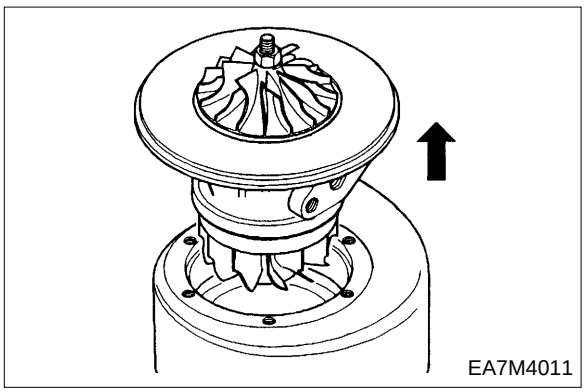

EA7M4009

Caution : *The compressor wheel blades can be easily damaged when the compressor housing is removed.*

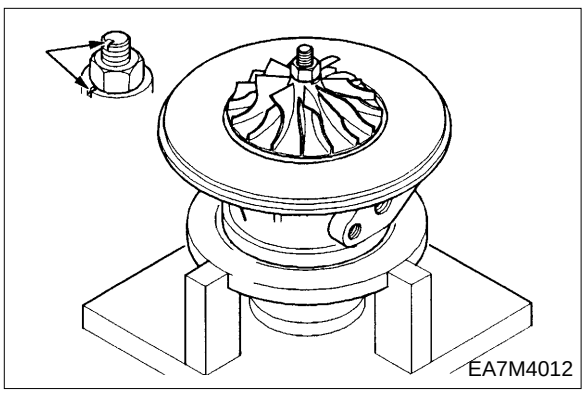
- Loosen and remove the 6 bolts (57) and clamp plates (88).


EA7M4010

Caution : *The turbine blades can be easily damaged when the turbine housing is removed*.


EA7M4011

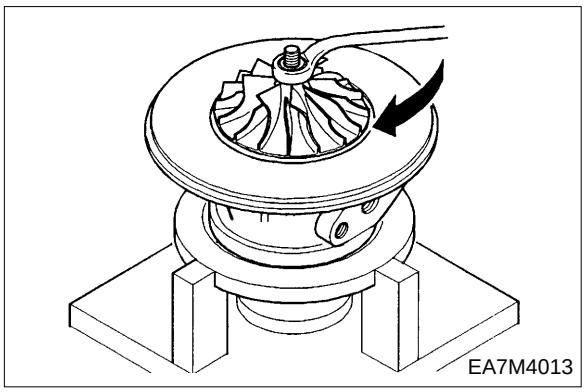
- Locate the Center Housing Rotating Assembly (CHRA) onto a 19mm socket clamped in the jaws of a vice or a suitable fixture.


EA7M4012

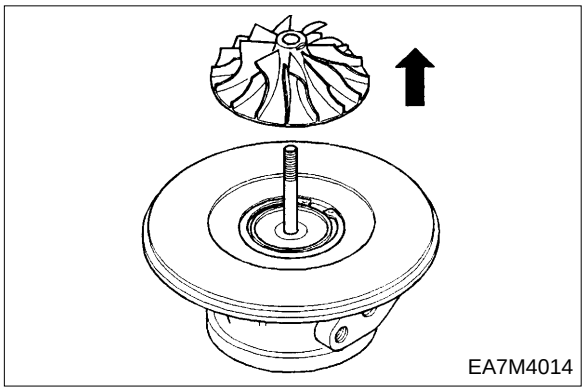
Caution : *Always make sure the turbine wheel shaft and the compressor wheel have alignment marks before disassembly of the CHRA.*

- Remove the compressor wheel lock nut (61).

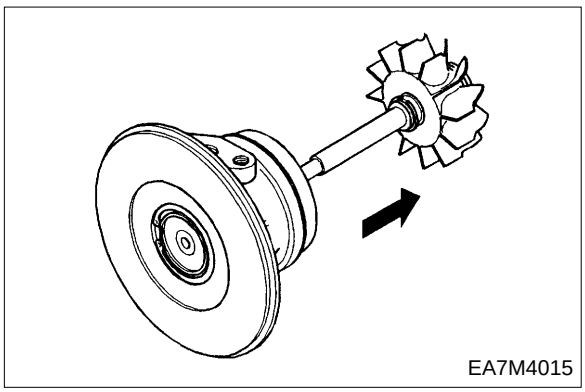
Note : *Left hand thread.*


EA7M4013

- Remove the compressor wheel (7).

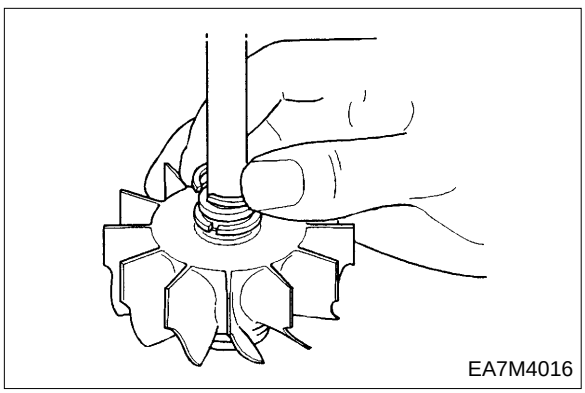

EA7M4014

- Remove the remaining CHRA from the socket and gently slide the shaft and wheel (6) from the bearing housing (4).

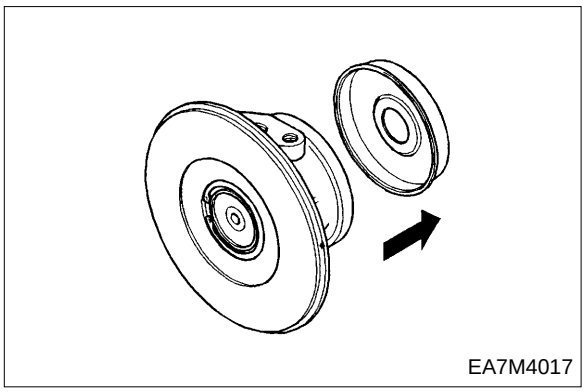

EA7M4015

- Discard the two piston ring seals (13).

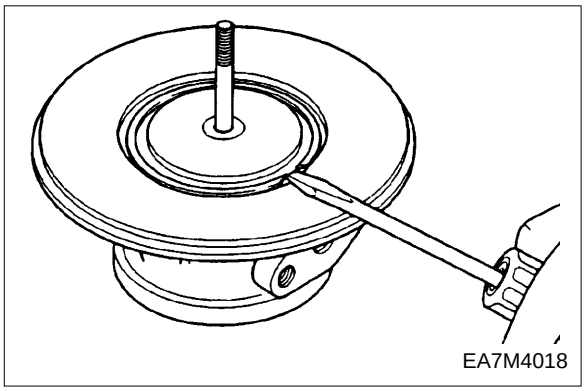
Caution : *Care should be taken not to score the assembly turbine wheel shaft.*


EA7M4016

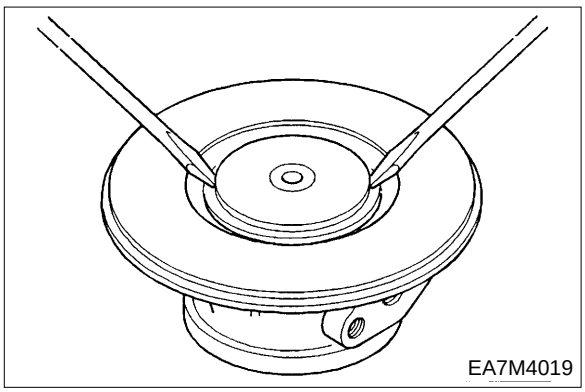
- Remove the heat shield (38).



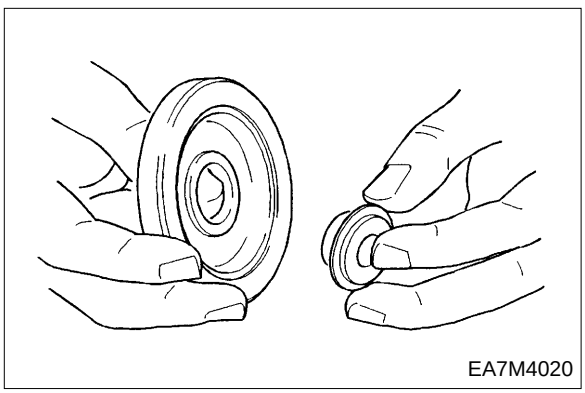
- Place the bearing housing on a flat surface and using a flat screwdriver, remove the insert retaining ring (66).



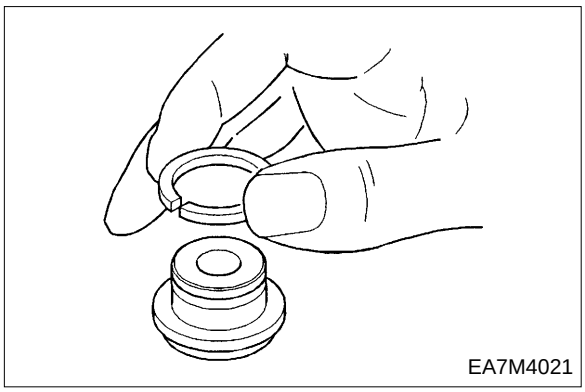
- Using two flat screwdrivers, gently remove the oil seal plate (43).



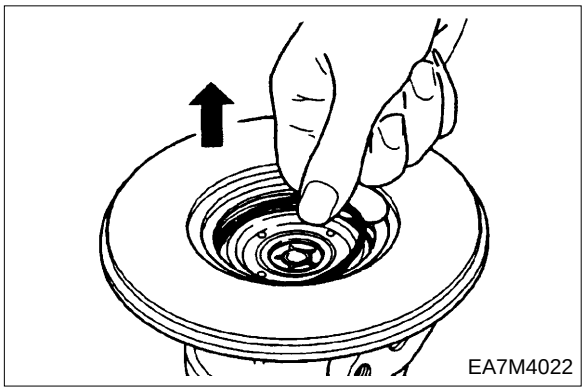
- Remove the oil slinger (31).



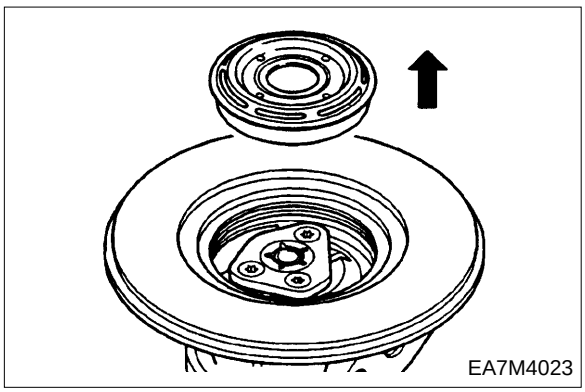
- Remove and discard the piston ring seal (16).



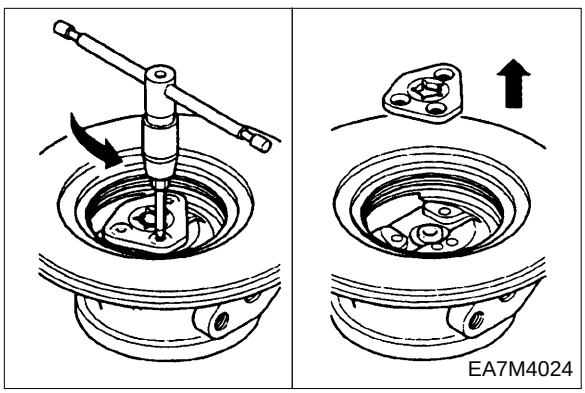
- Remove and discard the O ring seal (32).



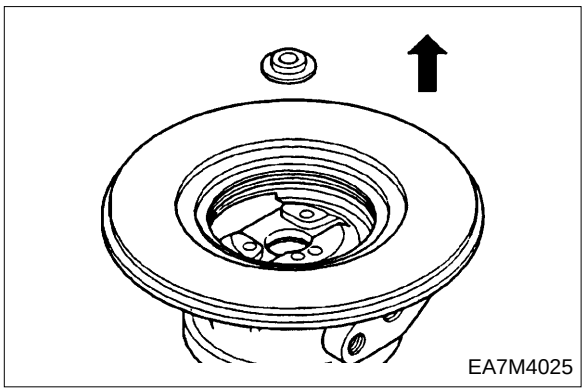
- Remove the oil baffle (33).



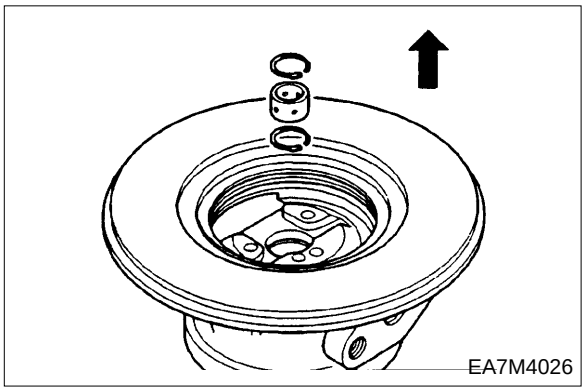
- Remove and discard the 3 flat head screws (58).
  Remove the thrust bearing (12).



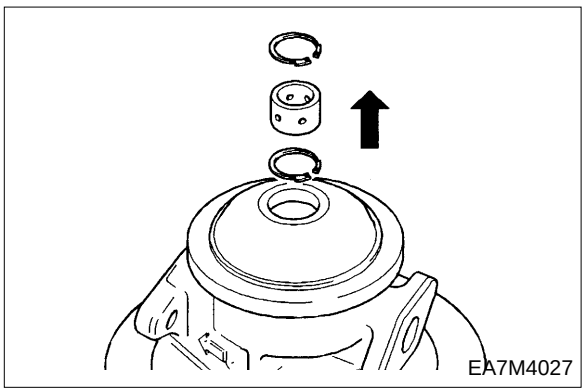
- If fitted remove the thrust bearing spacer (44).
  Remove the thrust collar (36). Also remove flat retaining ring (77) if fitted.



- Using circlip pliers, remove and discard the two circlips (64) and the journal bearing (11) from the compressor end.



- Turn the bearing housing over and repair the process.



3) Cleaning

With the turbocharger completely dismantled for overhaul, soak all the components in a non-caustic metal cleaner to loosen deposits. Bead blast the turbine housing if chemicals do not clean sufficiently.

On aluminium parts a bristle brush can be used. Never use a wire brush or metal scraper on any turbocharger component. Ensure that all the palls are finally cleaned with an air jet, especially drilled passages and machined apertures. Turbine Wheel: In the event of carbon build-up, it may be necessary so carefully blast the Piston Ring

Groove area of the turbine wheel using low grade shot medium.

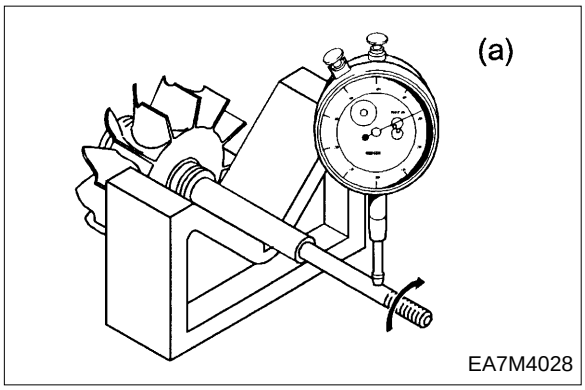
Caution : *Shot blasting specific areas for long periods of time may effect component balance.*

The surface adjacent to the turbine and compressor wheels on the stationary housings must be clean, smooth and free from deposits.

4) Inspection

Caution : *Do not attempt to straighten the turbine shaft.*

(a) Place the shaft on a vee block, using a dial gauge rotate the turbine wheel and check for movement on the dial gauge. Replace the assembly turbine wheel if it is bent. Max shaft bend allowed 0.025 mm (0.001 ins).

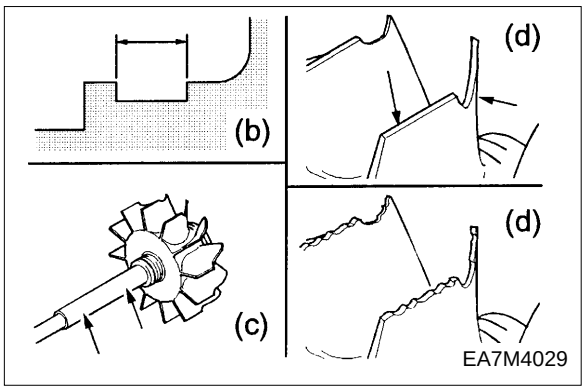


Shaft Bend (Max.)	mm	in.
	0.025	0.001

<Major Components>

- **Assembly Turbine Wheel (6)**

(b) Inspect the piston ring groove walls for wear.



Turbine wheel piston ring groove	mm	in.
Single ring (Min.)	1.664	0.0665
Twin ring (Min.)	3.538	0.1393

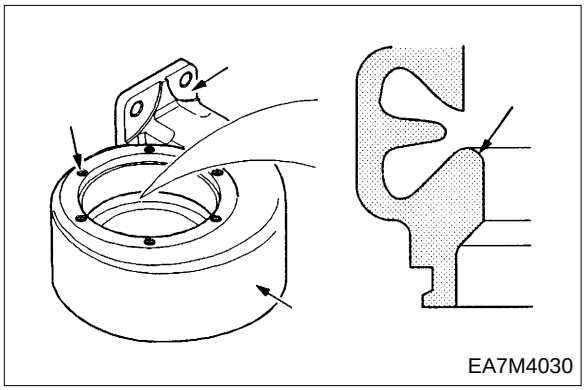
(c) Inspect the bearing journals for excessive scratches and wear. Minor light scratches may be tolerated.

Assembly turbine Wheel journals (Min.)	mm	in.
	3.538	0.1393

(d) Inspect for cracked, bent or damaged blades but **DO NOT ATTEMPT TO STRAIGHTEN BLADES.**

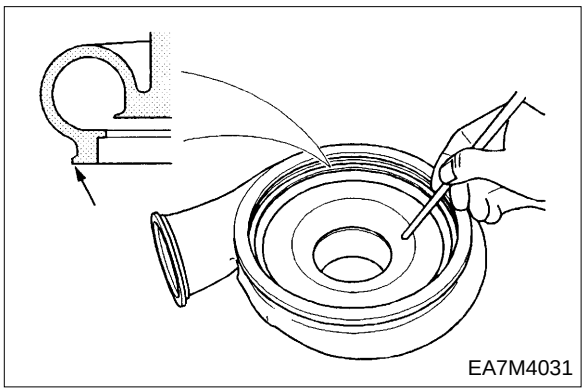
- **Turbine Housing (5)**

Inspect the profile for damage caused by possible contact with the rotor. Check all threads for damage. Inspect the outer and internal walls for cracks or flaking caused by overheating also check mounting flanges for signs of distortion.
Replace with new if any of the above are visible.


EA7M4030

- **Compressor Housing (8)**

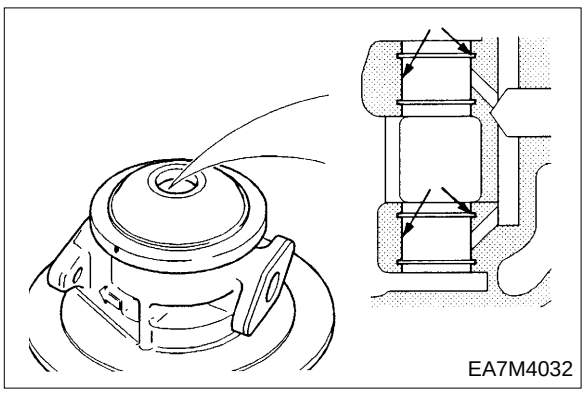
Inspect the profile for damage due to possible contact with the rotor. Check the V-band groove.
Replace with new if any of the above is visible.


EA7M4031

- **Bearing Housing (4)**

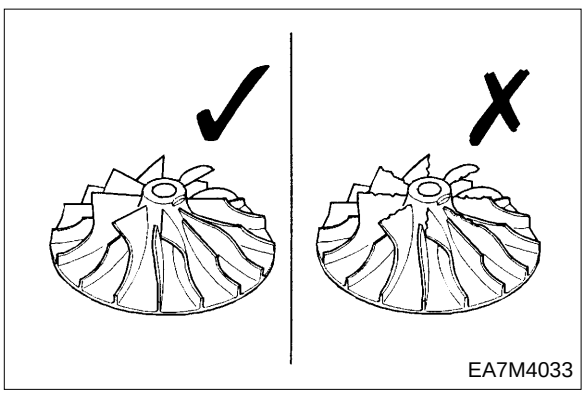
Inspect the bore for wear or score mark on both the bearing and piston ring area. Also check all tapped holes are clean and free from dirt.
Replace with new if any damage is found.

Bearing housing bore (Max.)	mm	in.
	19.063	0.7505


EA7M4032

- **Compressor Wheel (7)**

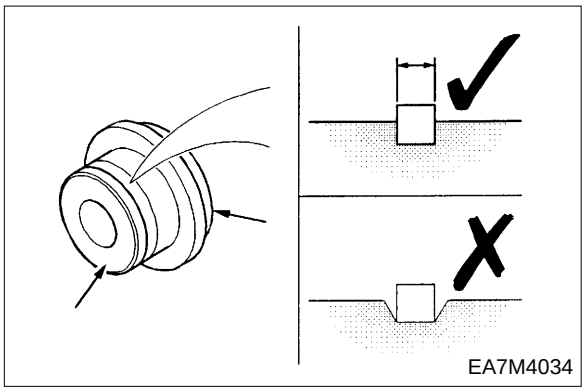
Inspect carefully for cracked, bent or damaged blades but **DO NOT ATTEMPT TO STRAIGHTEN BLADES.**
Replace with new if any damage is found.


EA7M4033

<Minor Components>

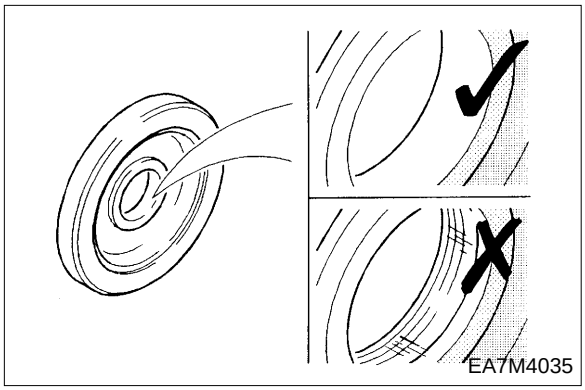
- **Oil slinger (31)**

Inspect and replace if the piston ring seal groove walls are scored or damaged. Also check for signs of rubbing on the flat surfaces.


EA7M4034

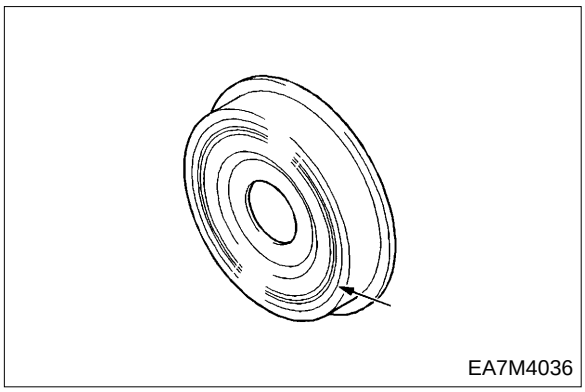
- **Oil seal plate (43)**

Inspect the seal bore, replace if scored or damaged.


EA7M4035

- **Heat shield (38)**

Check and replace if the heat shield id distorted or if signs of rubbing or cracking are visible.


EA7M4036

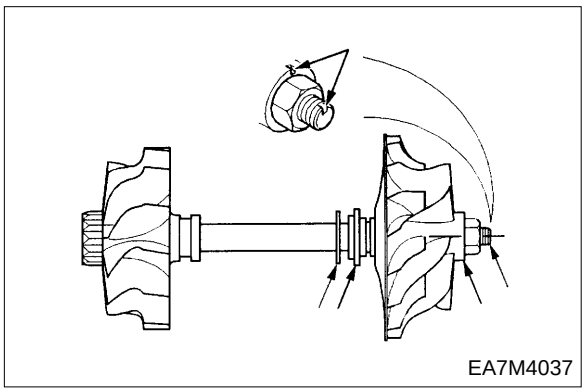
5) Assembly

- **Rotor balance**

Before assembly, always make sure that both compressor wheel and assembly turbine wheel are individually balanced.

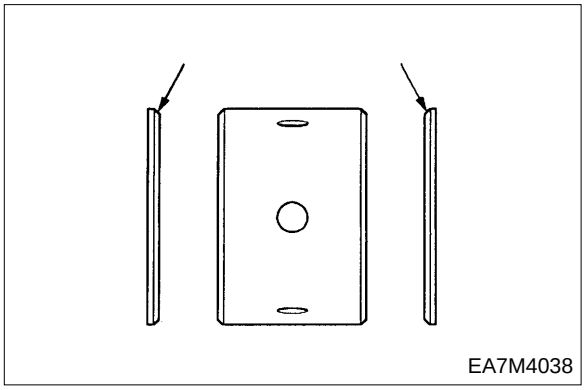
Then check balance of the rotor assembly to ensure it is within the required limits.

Mark up each individual item to help ensure correct alignment during assembly.


EA7M4037

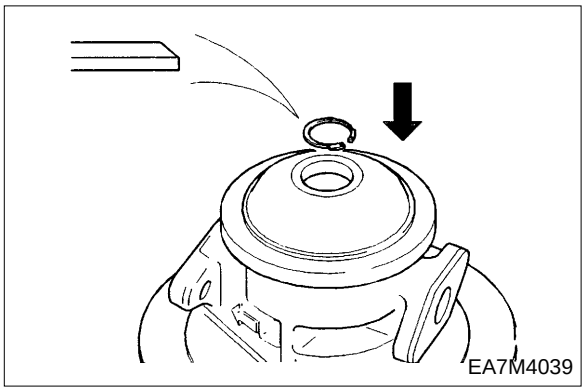
Rotor balance limits (Max.)	g.mm	oz. ins.
Turbine end	2.2	0.003
Compressor end	4.4	0.006

- Make sure that the circlips are always fitted with the bevelled edge facing the journal bearing.

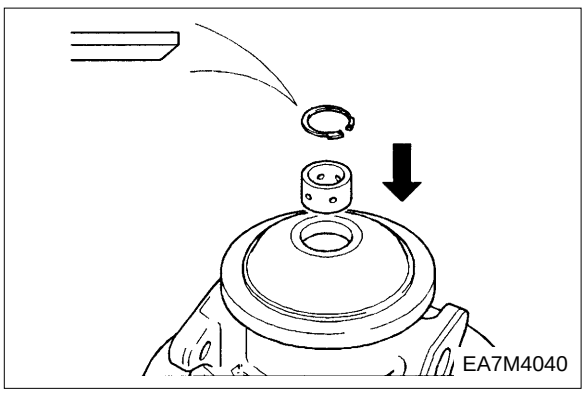


Caution : *Circlips (64). Premature failure will result if the circlips are fitted incorrectly.*

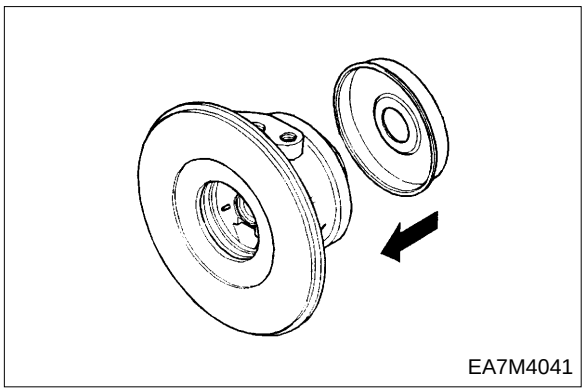
- Place the bearing housing (4) on a bench with the turbine end facing uppermost.
  Fit the inner circlip (64) with the bevelled edge facing upwards.



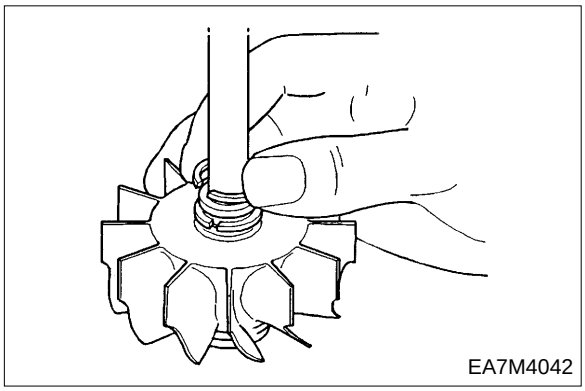
- Lubricate the journal bearing (11) and install into position.
  Fit the outer circlip (64) with the bevelled edge facing the bearing.
  Turn the bearing housing over and repeat the process.



- Install the heat shield (38).

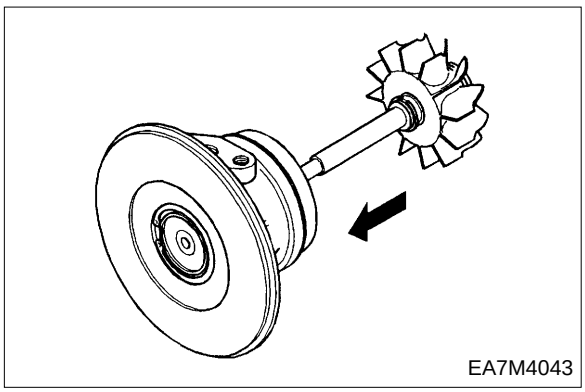

EA7M4041

- Install the two new piston ring seals (13) to the assembly turbine wheel (6).

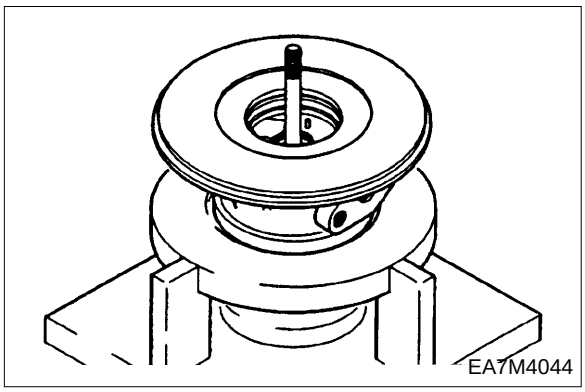

EA7M4042

- Lubricate the shaft using clean engine oil.

Caution : *Align the piston ring seals (13) so the gaps is positioned 180 ° from the oil drain hole. Gently press down on the turbine wheel - a slight rotation of the wheel will assist in properly locating the piston ring seals.*

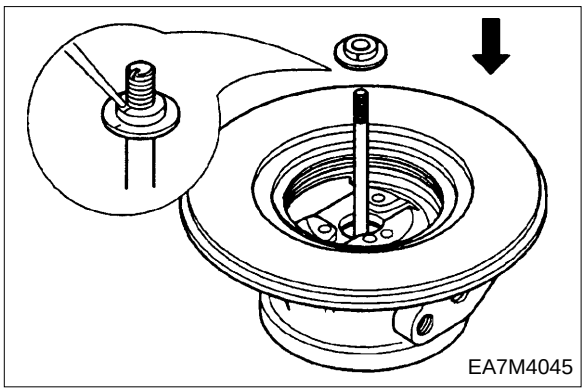

EA7M4043

- Support the assembly turbine wheel (6) and bearing housing in a suitable fixture.


EA7M4044

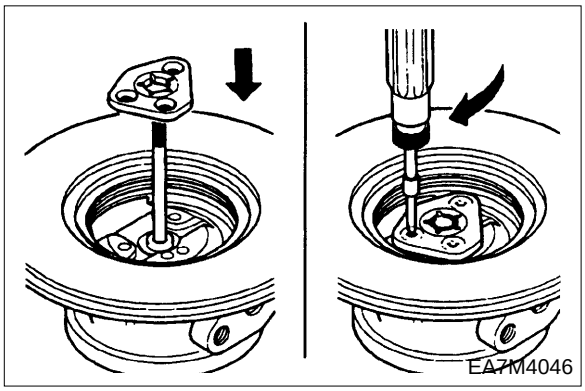
- Install the thrust bearing spacer (44) if fitted.
  Install the thrust collar (36).

Caution : *Align the balance mark on the thrust collar with that on the shaft.*

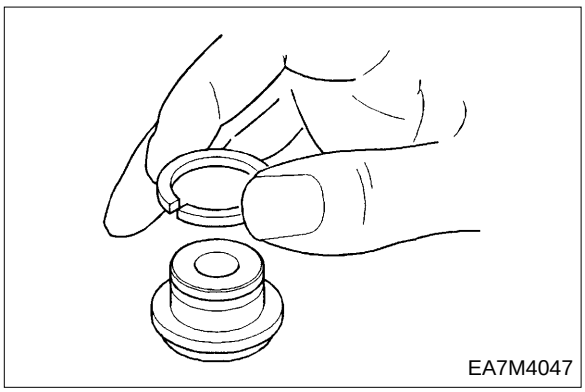

EA7M4045

- Using clean engine oil, lubricate the thrust bearing (12).
  Install the thrust bearing.
  Install the 3 flat hear screws (58).
  Using torque wrench, tighten to required torque.

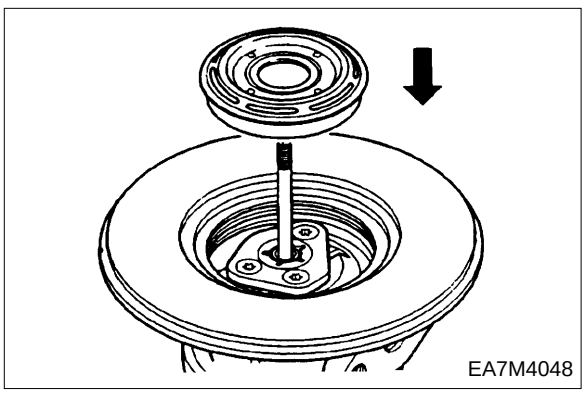
Torque value	Nm	in-lbs
	4.5	40


EA7M4046

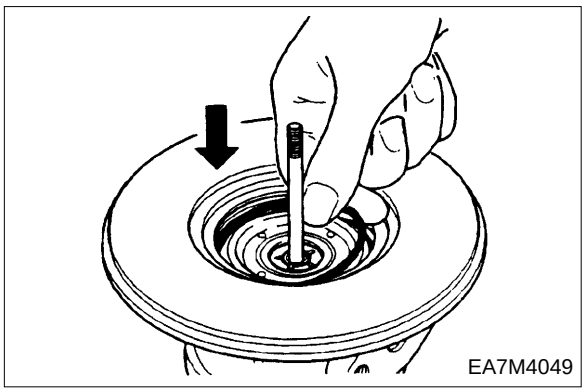
- Fit the new piston ring seal (16) to the oil slinger (31).


EA7M4047

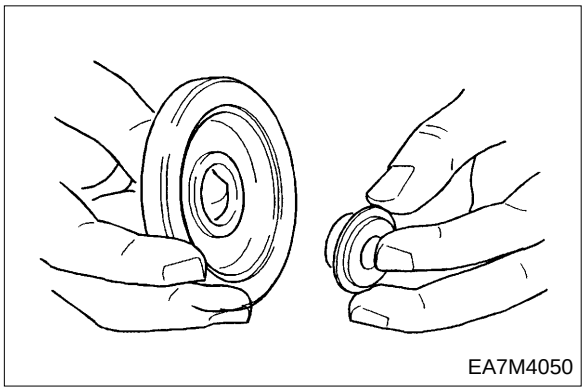
- Fit flat retaining ring (77) in base of bearing housing (4) if required.
  Install oil baffle (33).


EA7M4048

● Apply a small amount of oil to the O ring seal, install O ring seal (32).

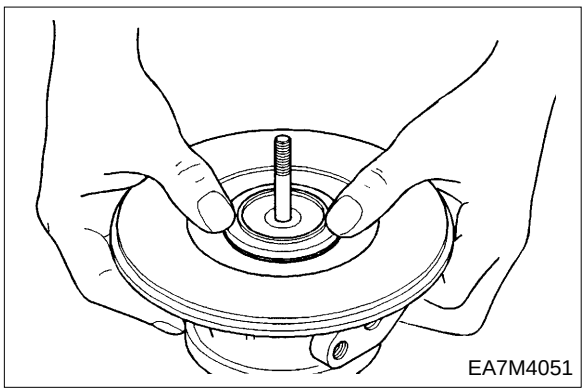

EA7M4049

● Insert the oil slinger (31) into the oil seal plate (43).

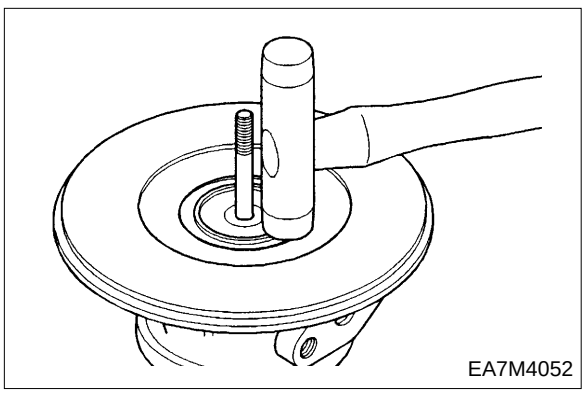

EA7M4050

● Install the oil seal plate (43) into the bearing housing (4).

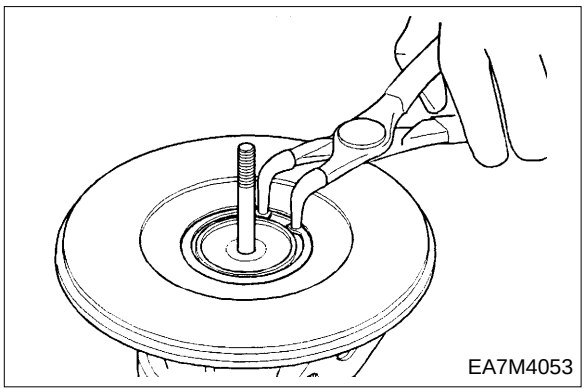
Caution : *Align the balance marks on the oil slinger (31) with that on the shaft end.*


EA7M4051

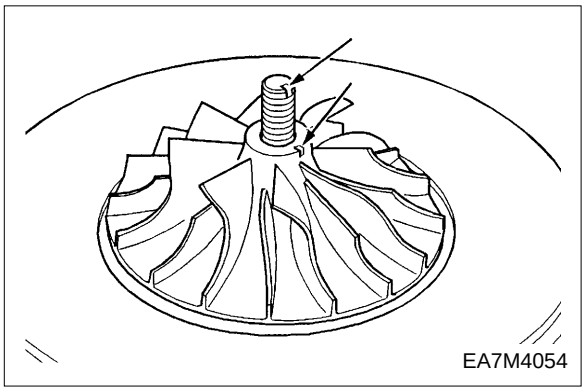
● Gently tap the oil seal plate (43) with a soft hammer to seat in position.


EA7M4052

● Install the retaining ring (66).
Check correct location using a screwdriver.


EA7M4053

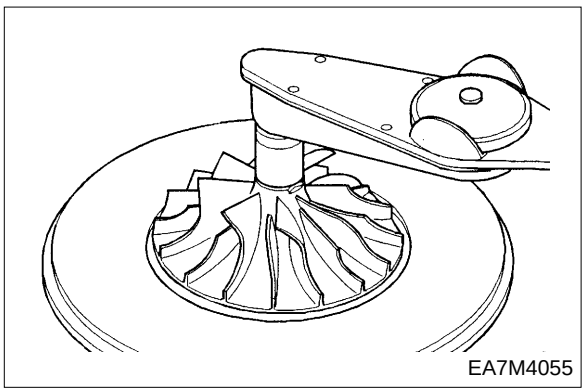
● Align the balance marks and install the compressor wheel (7).


EA7M4054

● Install the compressor wheel lock nut (61) and tighten to the torque value.

Note : *Left hand thread.*

Torque value	Nm	in-lbs
	17	150

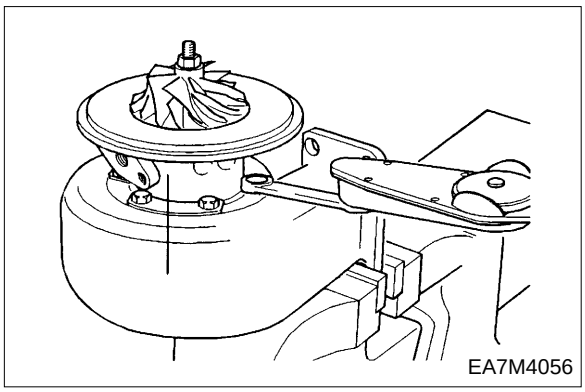

EA7M4055

Caution : *Ensure that the balance marks are aligned on the compressor wheel and the shaft.*

- Locate the CHRA into the turbine housing (5).

Install the 3 clamp plates (88) and tighten the 6 bolts (57) to the torque value.

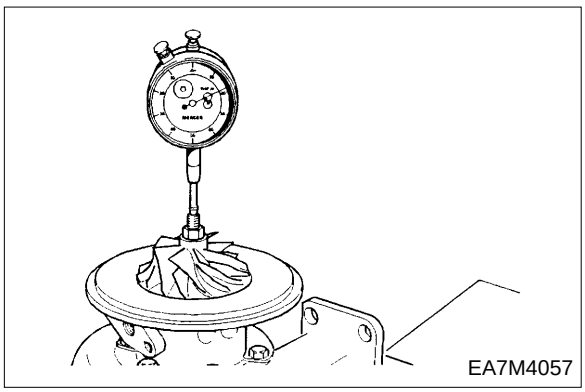
Torque value Bolts (57)	Nm	in-lbs
	20	180


EA7M4056

Caution : *Make sure the scribe marks are aligned.*

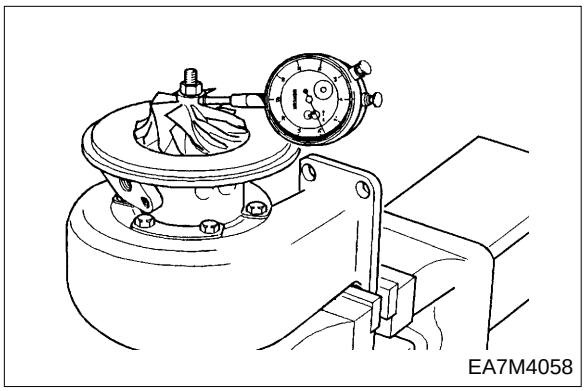
- Secure the turbine housing and check the trust clearance using a dial gauge.

Trust clearance	mm	in
Minimum	0.038	0.0015
Maximum	0.093	0.0037


EA7M4057

- Check the radial clearance using a dial gauge.

Radial clearance (H2D)	mm	in
Minimum	0.364	0.014
Maximum	0.550	0.022

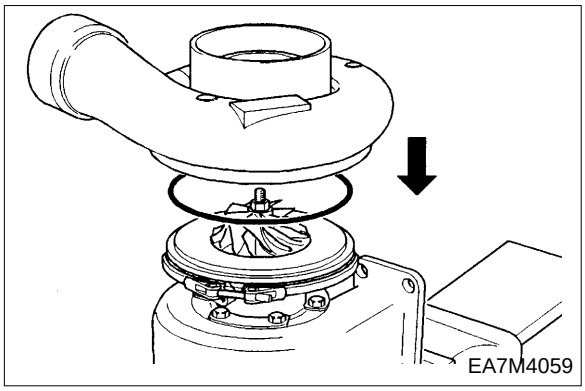

EA7M4058

- Loosely fit the V-band clamp.

Lubricate and install the O ring seal (41) if fitted.

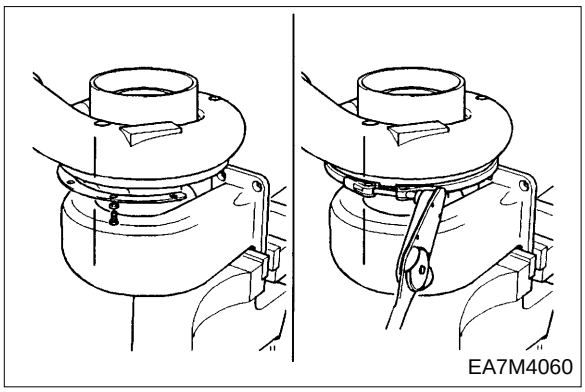
Install the compressor cover (8).

Caution : *The compressor wheel blades can be easily damaged when the compressor housing is installed.*


EA7M4059

- Install the 2 clamp plates (51), eight lock washers (54) and tighten the 8 bolts (59) to the torque value.
  Install the V-band clamp (29) and tighten the lock nut (62) to the torque value.

Trust value	Nm	in-lbs
Lock nut (62)	8.5	75
Bolts (57)	8.5	75

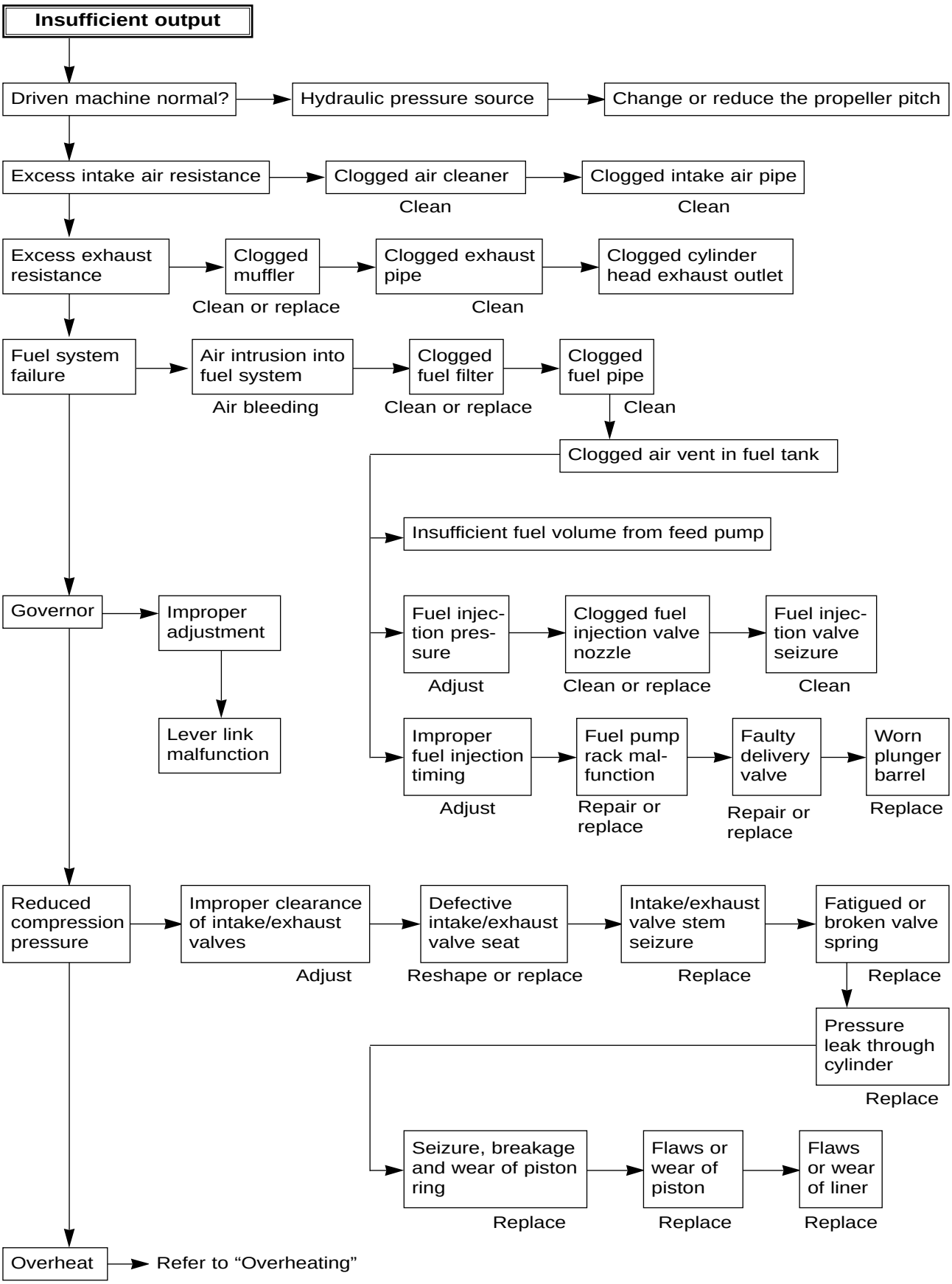

EA7M4060

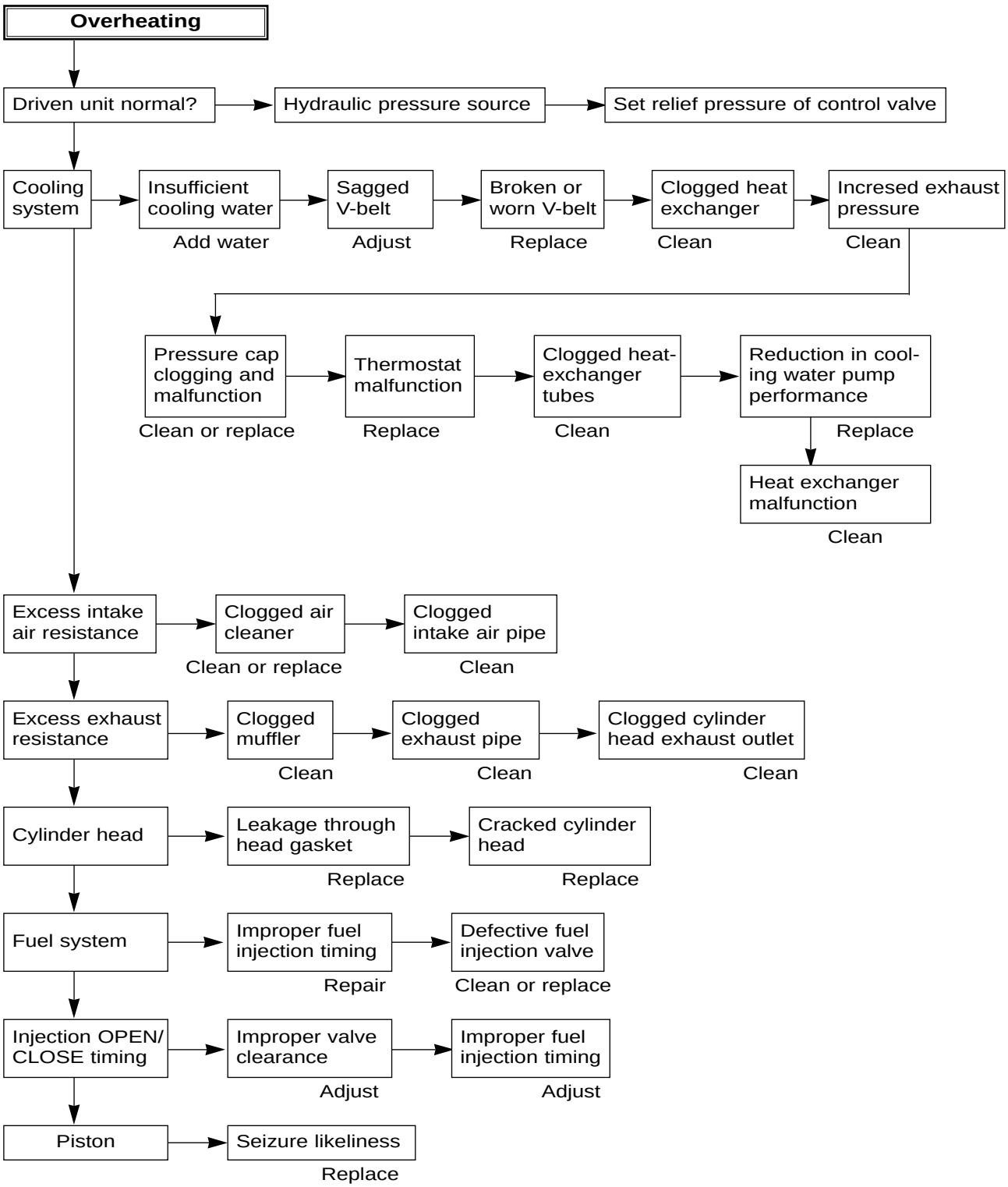
Caution : *Make sure the scribe marks are aligned.*

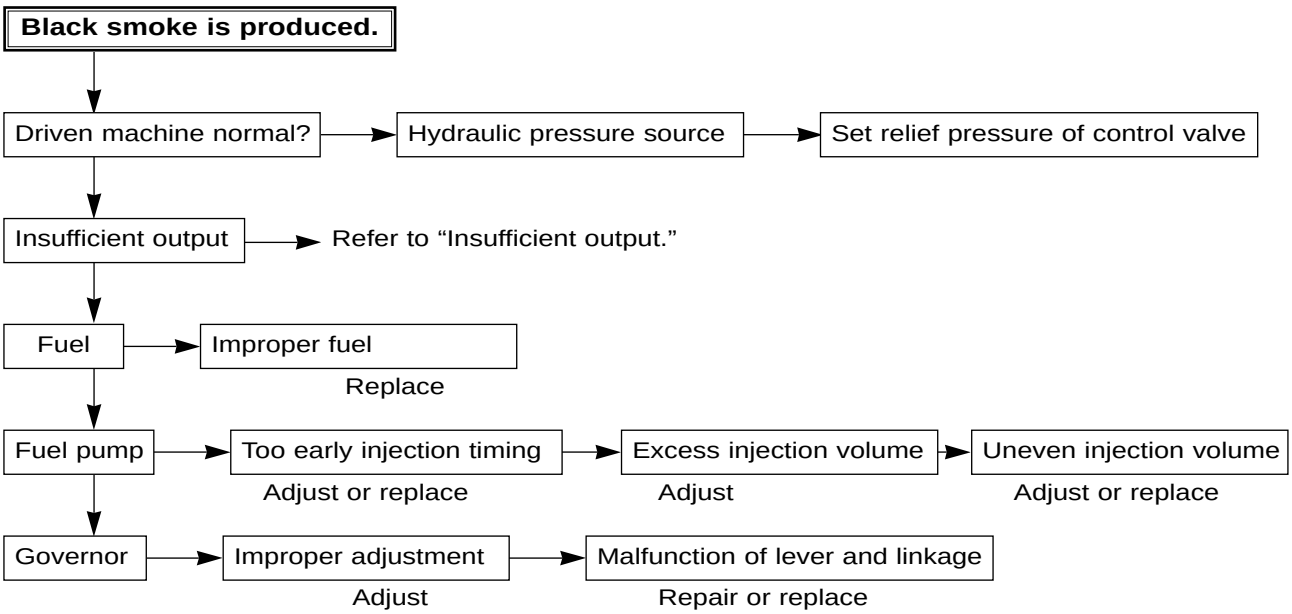
8. Troubleshooting

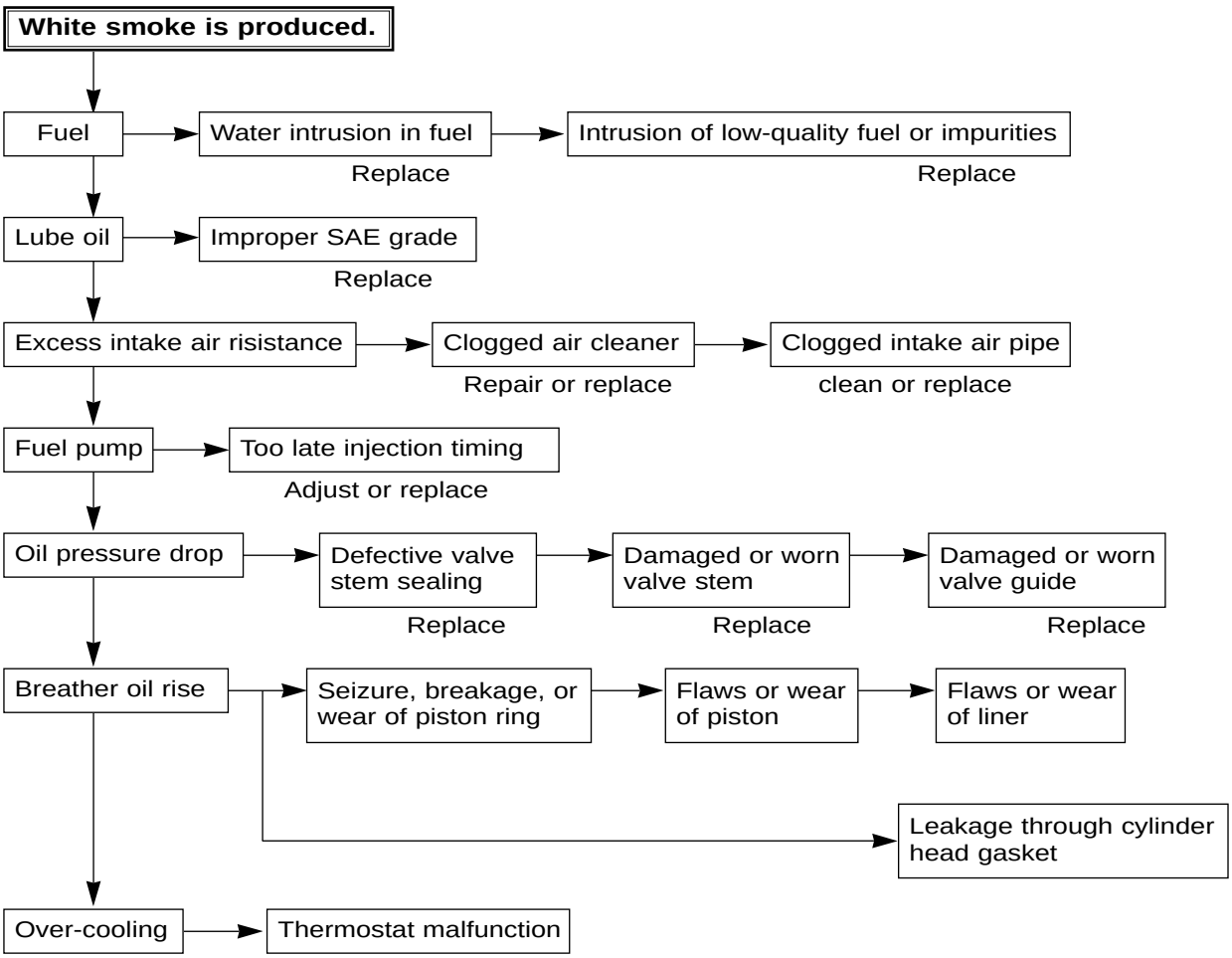
The following description summarizes the probable cause of and remedy for general failure by item. Immediate countermeasures should be taken before a failure is inflamed if any symptom is detected.

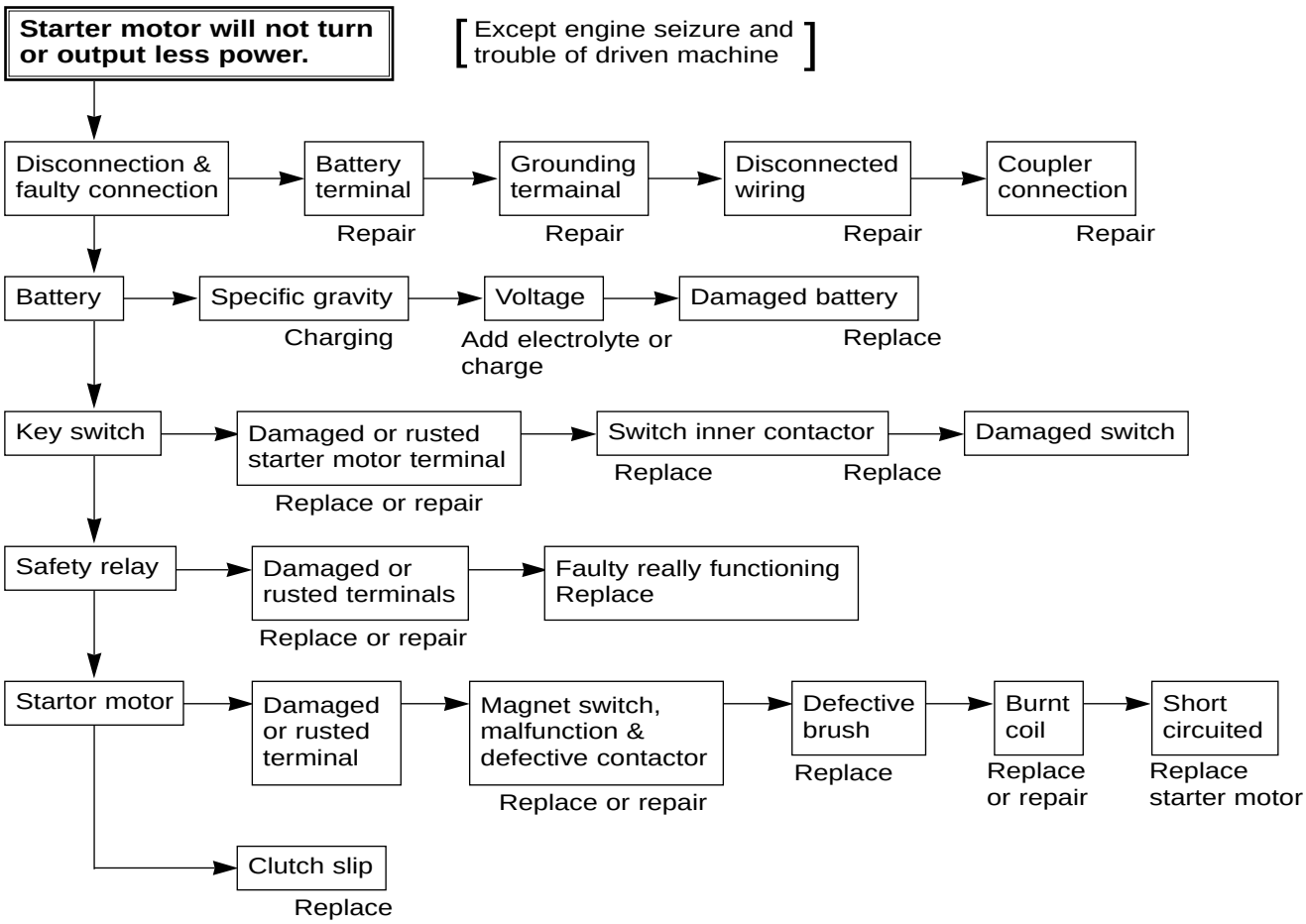
Hard to start the engine
Fuel system admits air
Bleed air (check feed pump)
Clogged fuel supply piping or clogged air vent pipe in tank.
Detect the cause and remove clogs or obstacles.
Clogged fuel filter
Replace filter element with a new one.
Fuel feed pump failure
Check for function. Service fuel pump or replace with a new one if less discharge volume is found.
Insufficient compression
Check according to “Insufficient output”
Improperly adjust valve stick or clearance in intake/exhaust vlaves.
Adjust clearance of intake/exhaust valves. Cheek valve guide, spring, and rocker arm mechanism for damage.
Improper injection timing or valve timing.
Check for injection timing and valve timing.
Clogged exhaust pipe (too high back pressure)
Totally check exhaust system (for dented or twisted pipes and clogged silencer, etc.)
Fuel injection valve failure or errors in selection types.
Check for part type No.
Service or replace fuel injection valves.
Fuel injection pump failure
Check, service or adjust.
Does starting-aid in cold weather function normally?
Check whether a proper voltage continuously occurs in low temperature starting-aid circuit while switch is turned ON.
When glow plugs are used, key switch is turned “HEAT” position of key switch.
If glow plug is reheated, engine starts.
If not, glow plugs fail or circuit is defective.
If fire once occurs, and goes out if starter motor is switched ON, voltage is insufficient or circuit is defective (such as erroneous selection of starter switch)


Insufficient output
Driven machine normal?
Hydraulic pressure source
Change or reduce the propeller pitch
Excess intake air resistance
Clogged air cleaner
Clean
Clogged intake air pipe
Clean
Excess exhaust resistance
Clogged muffler
Clean or replace
Clogged exhaust pipe
Clean
Clogged cylinder head exhaust outlet
Fuel system failure
Air intrusion into fuel system
Air bleeding
Clogged fuel filter
Clean or replace
Clogged fuel pipe
Clean
Clogged air vent in fuel tank
Insufficient fuel volume from feed pump
Governor
Improper adjustment
Lever link malfunction
Fuel injection pressure
Adjust
Clogged fuel injection valve nozzle
Clean or replace
Fuel injection valve seizure
Clean
Improper fuel injection timing
Adjust
Fuel pump rack malfunction
Repair or replace
Faulty delivery valve
Repair or replace
Worn plunger barrel
Replace
Reduced compression pressure
Improper clearance of intake/exhaust valves
Adjust
Defective intake/exhaust valve seat
Reshape or replace
Intake/exhaust valve stem seizure
Replace
Fatigued or broken valve spring
Replace
Pressure leak through cylinder
Replace
Seizure, breakage and wear of piston ring
Replace
Flaws or wear of piston
Replace
Flaws or wear of liner
Replace
Overheat
Refer to “Overheating”

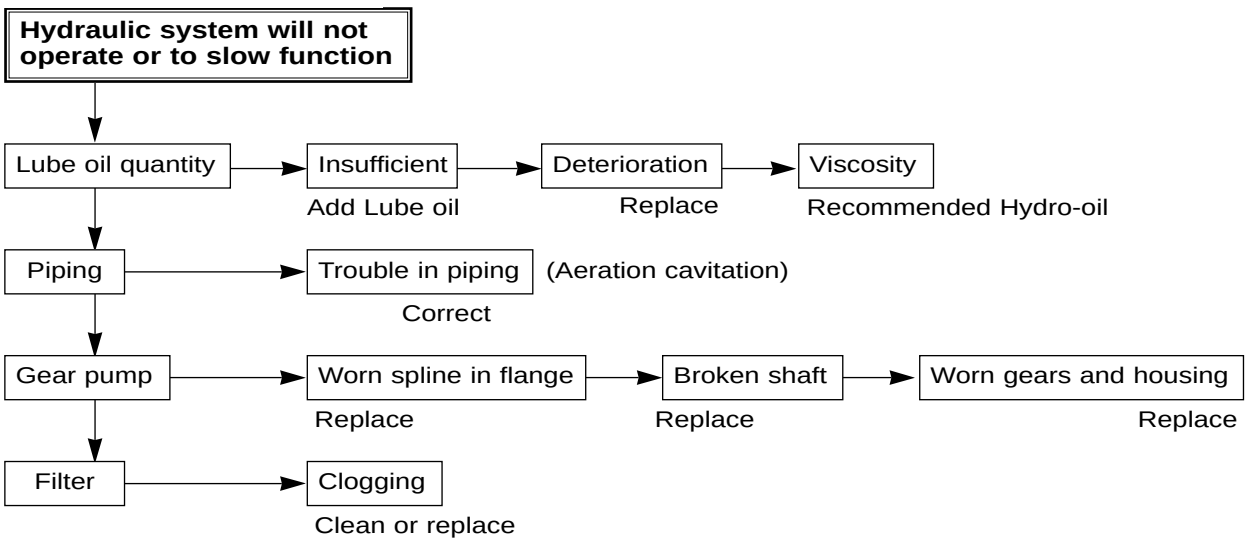

Overheating
Driven unit normal?
Hydraulic pressure source
Set relief pressure of control valve
Cooling system
Insufficient cooling water
Add water
Sagged V-belt
Adjust
Broken or worn V-belt
Replace
Clogged heat exchanger
Clean
Increased exhaust pressure
Clean
Pressure cap clogging and malfunction
Clean or replace
Thermostat malfunction
Replace
Clogged heat-exchanger tubes
Clean
Reduction in cooling water pump performance
Replace
Heat exchanger malfunction
Clean
Excess intake air resistance
Clogged air cleaner
Clean or replace
Clogged intake air pipe
Clean
Excess exhaust resistance
Clogged muffler
Clean
Clogged exhaust pipe
Clean
Clogged cylinder head exhaust outlet
Clean
Cylinder head
Leakage through head gasket
Replace
Cracked cylinder head
Replace
Fuel system
Improper fuel injection timing
Repair
Defective fuel injection valve
Clean or replace
Injection OPEN/ CLOSE timing
Improper valve clearance
Adjust
Improper fuel injection timing
Adjust
Piston
Seizure likeliness
Replace

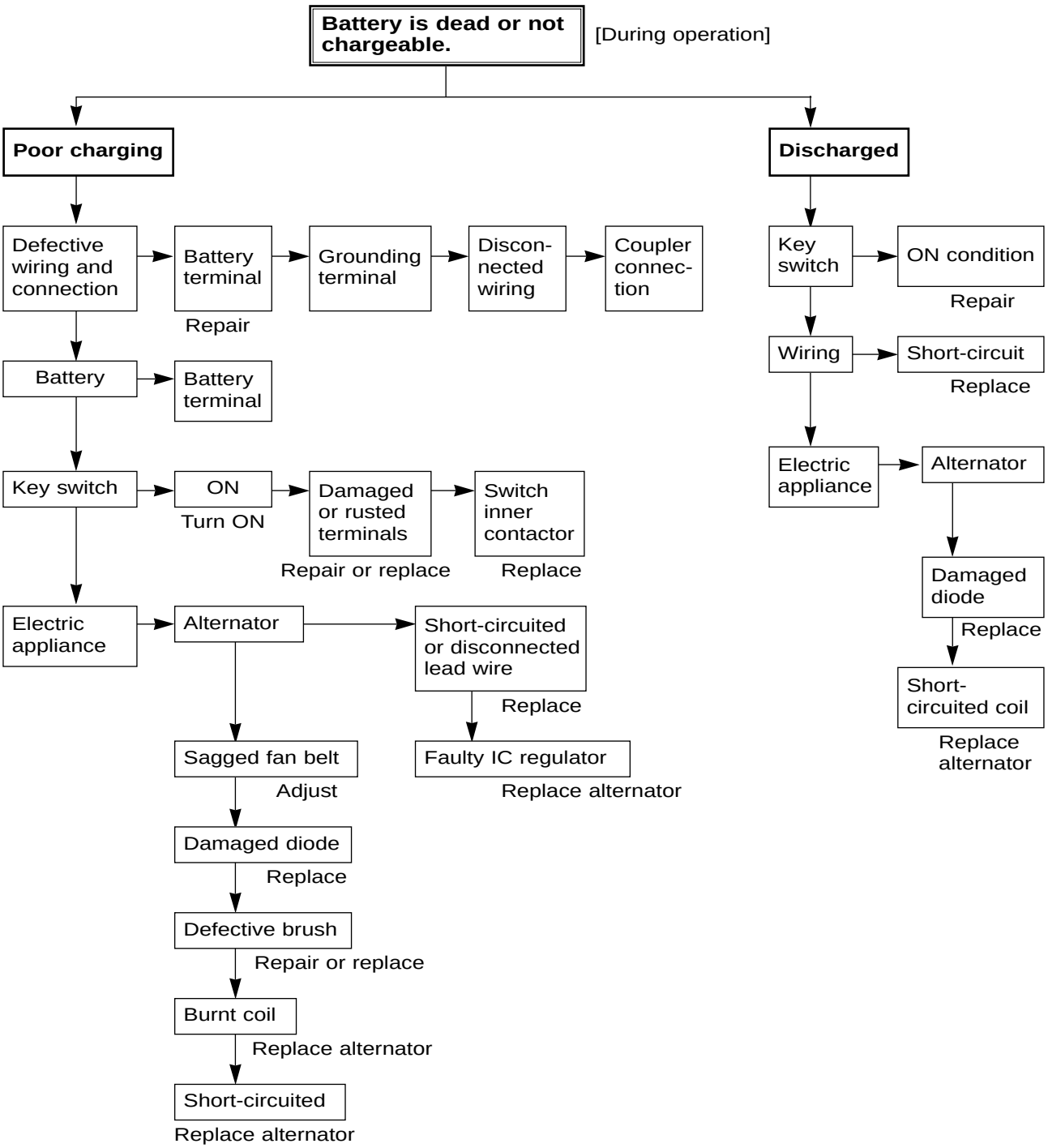

Black smoke is produced.
Driven machine normal?
Hydraulic pressure source
Set relief pressure of control valve
Insufficient output
Refer to “Insufficient output.”
Fuel
Improper fuel
Replace
Fuel pump
Too early injection timing
Adjust or replace
Excess injection volume
Adjust
Uneven injection volume
Adjust or replace
Governor
Improper adjustment
Adjust
Malfunction of lever and linkage
Repair or replace


White smoke is produced.
Fuel
Water intrusion in fuel
Replace
Intrusion of low-quality fuel or impurities
Replace
Lube oil
Improper SAE grade
Replace
Excess intake air risistance
Clogged air cleaner
Repair or replace
Clogged intake air pipe
clean or replace
Fuel pump
Too late injection timing
Adjust or replace
Oil pressure drop
Defective valve stem sealing
Replace
Damaged or worn valve stem
Replace
Damaged or worn valve guide
Replace
Breather oil rise
Seizure, breakage, or wear of piston ring
Flaws or wear of piston
Flaws or wear of liner
Leakage through cylinder head gasket
Over-cooling
Thermostat malfunction

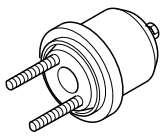
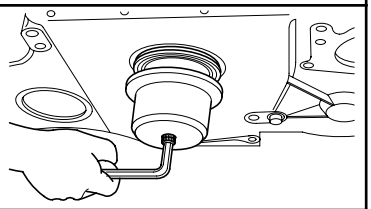
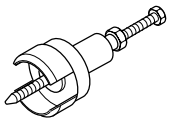
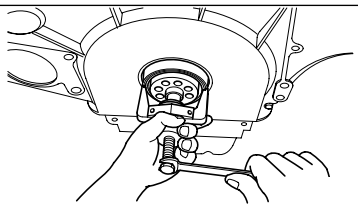
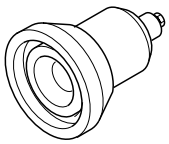
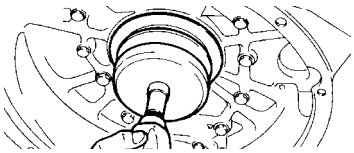
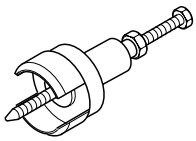
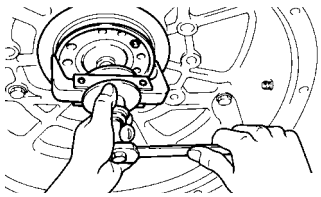
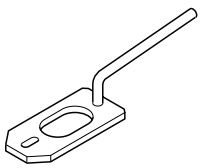
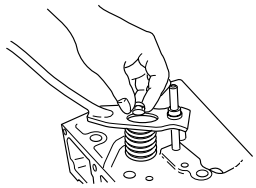
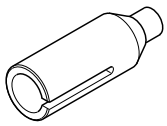
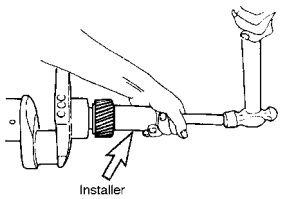
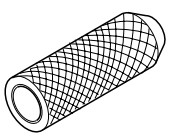
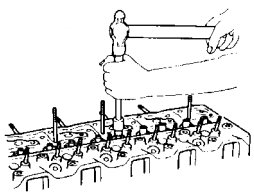
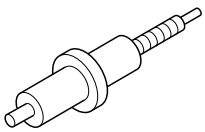
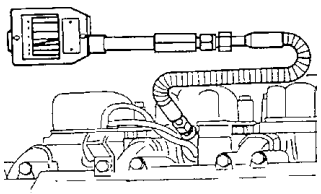


Hydraulic pressure source

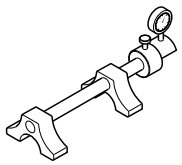
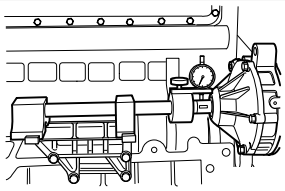
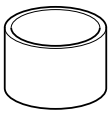
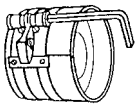
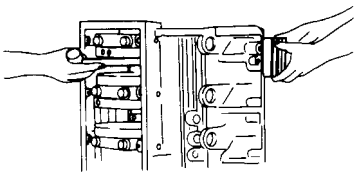
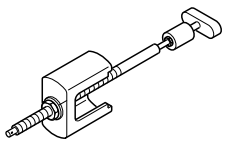
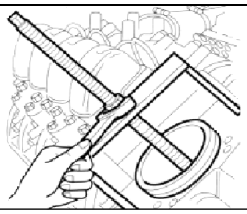
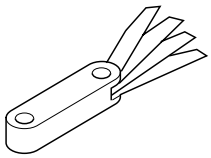
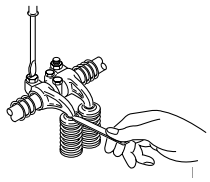
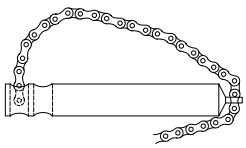
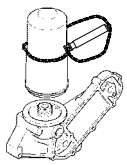
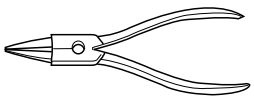
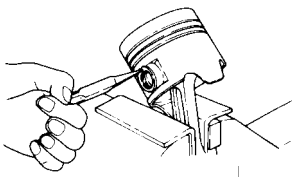
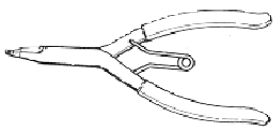
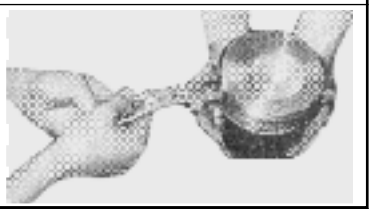



Battery is dead or not chargeable.
[During operation]
Poor charging
Discharged
Defective wiring and connection
Battery terminal
Repair
Grounding terminal
Discon-nected wiring
Coupler connec-tion
Battery
Battery terminal
Key switch
ON
Turn ON
Damaged or rusted terminals
Repair or replace
Switch inner contactor
Replace
Electric appliance
Alternator
Short-circuited or disconnected lead wire
Replace
Faulty IC regulator
Replace alternator
Sagged fan belt
Adjust
Damaged diode
Replace
Defective brush
Repair or replace
Burnt coil
Replace alternator
Short-circuited
Replace alternator
Key switch
ON condition
Repair
Wiring
Short-circuit
Replace
Electric appliance
Alternator
Damaged diode
Replace
Short-circuited coil
Replace alternator

9. Special Tool List

No.	Tool Names	Tool No.	Descriptions	Applications
1	Front Oil Seal Assembly Jig	EF.123-173(NOK)		
2	Front Oil Seal Puller Jig	EF.123-052		
3	Rear Oil Seal Assembly Jig	EF.123-184(NOK)		
4	Rear Oil Seal Puller Jig	EF.123-048		
5	Valve Spring Press	EF.123-065		
6	Crank Shaft Gear Punch	EU.2-0647		
7	Valve Stem Seal Punch	EF.122-089		
8	Adapter for Cylinder Pressure Test	EU.2-0530		

No. 3 : CR (U.S.A CR Industries Co.) NOK (Japan NOK Co.)

No.	Tool Names	Tool No.	Descriptions	Applications
9	Injection Pump Alignment Jig	EF123-015 (Only L086TI)		
10	Piston Sleeve	EF.123-064	 EF.120-208 (For all engines) 	
11	Cylinder Liner Puller	EF.123-086		
12	Filler Gauge	60.99901-0027		
13	Filter Wrench	65.98801-0001		
14	Snap Ring Plier	T7610001E		
15	Piston Ring Plier	T7621010E		

10. Tightening Torque

● Tightening torque for major parts

Major Parts	Screw (diameter x pitch)	Strength (grade)	Tightening Torque	Remarks
Cylinder head bolt	M14 x 1.5	10.9T	6.0 kg·m + 180 + 150 (Angle)	
Connecting rod bearing cap bolt	M14 x 1.5	12.9T	18.0 kg·m	
Crankshaft main bearing cap bolt	M16 x 1.5	12.9T	30.0 kg·m	
Balance weight fixing bolt	M12 x 1.5	10.9T	10.0 kg·m	
Flywheel fixing bolt	M14 x 1.5	10.9T	21.5 kg·m	
Crankshaft gear fixing bolt	M12 x 1.5	10.9T	13.0 kg·m	

● Tightening torque for injection pump system

Parts	Tightening Torque
Injection pump delivery valve holder	11.0 ~ 12.0 kg·m
Nozzle holder fixing cap nut to cylinder head	7.0 kg·m
Nozzle fixing cap nut of nozzle holder	6.0 ~ 8.0 kg·m
High pressure injection pipe fixing cap nut	Max. 2.9 ~ 3.2 kg·m

● Tightening torque table for standard bolt

Refer to the following table for bolts other than described above.

Diameter x pitch (mm)	Degree of strength										
	3.6	4.6	4.8	5.6	5.8	6.6	6.8	6.9	8.8	10.9	12.9
	(4A)	(4D)	(4S)	(5D)	(5S)	(6D)	(6S)	(6G)	(8G)	(10K)	(12K)
	Limit value for elasticity (kg/mm²)										
	20	24	32	30	40	36	48	54	64	90	108
	Tightening torque (kg•m)										
M5	0.15	0.16	0.25	0.22	0.31	0.28	0.43	0.48	0.50	0.75	0.90
M6	0.28	0.30	0.45	0.40	0.55	0.47	0.77	0.85	0.90	1.25	0.5
M7	0.43	0.46	0.70	0.63	0.83	0.78	1.20	1.30	1.40	1.95	2.35
M8	0.70	0.75	1.10	1.00	1.40	1.25	1.90	2.10	2.20	3.10	3.80
M8x1	0.73	0.80	1.20	1.10	1.50	1.34	2.10	2.30	2.40	3.35	4.10
M10	1.35	1.40	2.20	1.90	2.70	2.35	3.70	4.20	4.40	6.20	7.40
M10x1	1.50	1.60	2.50	2.10	3.10	2.80	4.30	4.90	5.00	7.00	8.40
M12	2.40	2.50	3.70	3.30	4.70	4.20	6.30	7.20	7.50	10.50	12.50
M12x1.5	2.55	2.70	4.00	3.50	5.00	4.60	6.80	7.70	8.00	11.20	13.40
M14	3.70	3.90	6.00	5.20	7.50	7.00	10.00	11.50	12.00	17.00	20.00
M14x1.5	4.10	4.30	6.60	5.70	8.30	7.50	11.10	12.50	13.00	18.50	22.00
M16	5.60	6.00	9.00	8.00	11.50	10.50	17.90	18.50	18.00	26.00	31.00
M6x1.5	6.20	6.50	9.70	8.60	12.50	11.30	17.00	19.50	20.00	28.00	33.00
M18	7.80	8.30	12.50	11.00	16.00	14.50	21.00	24.20	25.00	36.00	43.00
M18x1.5	9.10	9.50	14.50	12.50	18.50	16.70	24.50	27.50	28.00	41.00	49.00
M20	11.50	12.00	18.00	16.00	22.00	19.00	31.50	35.00	36.00	51.00	60.00
M20x1.5	12.80	13.50	20.50	18.00	25.00	22.50	35.00	39.50	41.00	58.00	68.00
M22	15.50	16.00	24.50	21.00	30.00	26.00	42.00	46.00	49.00	67.00	75.00
M22x1.5	17.00	18.50	28.00	24.00	34.00	29.00	47.00	52.00	56.00	75.00	85.00
M24	20.50	21.50	33.00	27.00	40.00	34.00	55.00	58.00	63.00	82.00	92.00
M24x1.5	23.00	25.00	37.00	31.00	45.00	38.00	61.00	67.00	74.00	93.00	103.00

Others : 1. The above torque rating have been determined to 70% or so of the limit value for bolt elasticity.

2. Tension is calculated by multiplying tensile strength by cross section of thread.
3. Special screws should be tightened to 85% or so of the standard value.
   For example, a screw coated with MoS2 should be tightened to 60% or so of the standard value.

11. Maintenance Specification Table for Major Parts

Group	Part	Inspection Item		Stand value for assembly	Limit for use	Correction	Remark
Engine body	Cylinder block & liner	Inside diameter of cylinder liner for wear		ø111~ø111.022	ø111.222 (Limit0.2)	Replace liner	-
		Amount of liner projection		0.03~0.08		Need amount of projection without fail	Projection difference between adjacent liners : 0.15 ↓
		The flatness of upper surface of cylinder block		0.05/200		Correct with a surface grinder	Referenced length : 200mm
		Hydraulic test for 1 minute (kg/cm²)		4		Replace if leaky	
	Cylinder head & valve	Valve seat depression	Intake	0~0.3	-	Replace valve seat	
			Exhaust	0~0.3	-		
		Cylinder head height		109.9 ~110.1	108.4	Replace cyl. head	
		Hydraulic test for 1 minute (kg/cm²)		4		Replace if leaky	Water temp. 70˚C
Major moving parts	Piston	Outer dia. piston		ø110.801~ ø110.959		Replace liner	Measure at 13mm away from lower surface of piston
		Clearance between piston and liner		0.041~0.221	0.3	Replace one worn more	
		Width of piston ring grooves	Top ring	3.50		Replace piston if groove width is beyond specified value	
			2nd ring	3.06~3.08			
			Oil ring	4.04~4.06			
		Piston projection from cylinder block upper surface		0~0.12		Must exist	Measure unworn portion beneath the rim of the upper side
		Permissible weight difference of each piston		±15 g	96 g ↓	Replace piston	
	Piston ring	Piston ring gap	Top ring	0.40~0.65	1.5	Replace ring	Standard gauge inside diameter : ø108
			2nd ring	0.40~0.65	1.5		
			Oil ring	0.30~0.60	1.5		
		Piston ring side clearance	Top ring			Replace ring or piston	Limit for use if for standard clearance
			2nd ring	0.07~0.102	0.15		
			Oil ring	0.05~0.085	0.15		
		Direction of ring gap				Cross Install by 120˚C	
	Piston pin	Outer diameter of piston pin		ø41.994~42		Replace piston pin	
		Clearance between piston pin and its bush		0.009~0.015		Replace one worn more	

Group	Part	Inspection Item	Stand value for assembly	Limit for use	Correction	Remark
Major moving parts	Crank shaft	Radial run-out of journal and pin		0.01	Correct with a grinder	Measure In horizontal and vertical directions
		Outside diameter of journal	∅83.966~ ∅83.988	∅83	Use under sized bearings	
		Outside diameter of pin	∅70.971~ ∅70.990	∅70	respectively(0.25, 0.5, 0.75, 1.0)	
		Ellipticity of journal and pin	0.008	0.025		
		Concentricity of journal and pin	0.01	0.03		
		Taper of journal and pin	0.01	0.03		
		Clearance between crankshaft and bearing	0.052~0.122	0.25	Replace bearing	Measure at crown part not parting line
		End play of crankshaft	0.15~0.325	0.5	Replace thrust bearing	
		Run-out of crankshaft	0.1 ↓		Adjust by a press if bended	Measure at No.4 bearing(No. 1 & 7 bearing supported)
		Balance of crankshaft(g•cm)	60 ↓	60 or less	Check dynamic balance	Measure at 400 rpm
		Torque valve journal bearing cap bolt (kg•m)	30		Coat the bolt with engine oil	Clean out foreign objects on joining surface
		Crush height of journal bearing	0.08~0.110			Measure after tightening metal cap and releasing one stud
		Oil seal for wear(crank shaft rear)			Replace oil seal if oil leaking	
	Connec-ting rod	End play of con-rod	0.170 ~ 0.248	0.50	Replace con-rod	
		Clearance between con-rod bearing and crank pin	0.034 ~ 0.098	0.25	Replace bearing	
		Clearance between small end bush & piston pin	0.050~0.081	0.12		Measure after installing the bearing and releasing one bolt
		Crush height of con-rod bearing	0.30~0.50			After completing of bearing loosen one stud bolt & measure
		Side clearance of big-end and small-end		0.50	Replace con-rod	
		Allowable weight difference per con-rods	18 g ↓			
		Torque valve of con-rod bearing cap bolt (kg•m)	18		Coat the bolt with engine oil	Clean out foreign objects on joining surface
	Cam shaft	Diameter of cam shaft journal	∅57.86~ ∅57.88			
		Clearance between cam shaft and cam bush	0.12~0.17	0.24	Replace cam bush	
		End play of camshaft	0.28~0.43	0.6	Replace thrust washer	
		Run-out of camshaft		0.1	Correct or replace the cam shaft	
	Timing gear	Clearance between idle shaft bush and idle shaft	0.025~0.091	0.15		
		End play of idle gear shaft	0.043~0.167	0.3	Correct or replace gear	
		Back-lash between gears(cam, idle, crank and injection)	0.16~0.28	0.35	Replace gear	

Group	Part	Inspection Item		Stand value for assembly	Limit for use	Correction	Remark
Valve system	Valve	Diameter of intake valve stem		ø8.950~ø8.970	0.02	Replace valve & valve guide	When replacing valve, replace valve guide alike
		Diameter of exhaust valve stem		ø8.935~ø8.955	0.02		
		Clearance between valve stem and valve guide	Intake	0.030~0.065	0.15	Replace valve & valve guide	Replace one worn more
			Exhaust	0.045~0.080	0.15		
		Thickness of valve head	Intake	2.7	Max. 1	Replace valve	
			Exhaust	2.2			
		Clearance between valve guide and valve spring seat	Intake	1.0			
			Exhaust	1.0			
		Clearance between valve guide and cyl. head installing hole		-0.039~-0.010 (Press fit)			Spread oil over valve guide and press it into the hole
		Concentricity between valve stem and valve head		0.15			Without spring seat
		Intake valve spring	Free length	Approx.64		Replace valve spring	
			Tension force (when pressed to 41mm)kg	67.9~72.1	66.5		
			Squareness (along free length direction)	2.5°			
		Exhaust valve spring	Inner Free length	Approx.60		Replace valve spring	
			Inner Tension force(when pressed to 38mm)kg	26.9~30.3	-		
			Inner Squreness (along free length direction)	2.5°			
			Outer Free length	Approx. 71		Replace valve spring	
			Outer Tension force(when pressed to 41mm)kg	62.7~69.3	-		
			Outer Squreness (along free length direction)	2.5°	-		
		Valve clearance (at cold)	Intake	0.3	Adjust		
			Exhaust	0.3			
		Joining surface of valve stem and rocker arm bush				Grind or replace if severely pitted on tip of rocker arm and stem	
		Clearance between rocker arm shaft & rocker arm bush		0.020~0.093	0.25	Replace bush or shaft	
		Diameter of rocker arm shaft for wear		ø23.939~ ø23.96	ø23.75	Replace	
		Run-out of push rod		-	0.3	Replace	

Group	Part	Inspection Item	Stand value for assembly	Limit for use	Correction	Remark
Valve system	Tappet	Clearance between tappet & cyl. block	0.035 ~ 0.077	0.1	Replace tappet	
		Diameter of tappet	∅19.944 ~ ∅19.965	19.89	Replace tappet	
		Tappet face in contact with cam	-	-	Replace if severely worn or deformed	
Lubricating system	Oil pressure	Oil pressure (normal speed)kg/cm²	4.8 or less	3.5	Check oil leakage and clearance between each part	
		Oil pressure (idling)kg/cm²	0.8~1.4	0.6	Use recommended oil	
	Oil temperature	Max. permissible oil temperature˚C	-	105		Must not exceed this valve
		Permissible oil temperature in short time˚C	-	120		
	Oil pump	Axial play of oil pump gear	0.055 ~ 0.105	-	Replace gear or cover	
		Clearance between drive gear shaft & oil pump cover hole	0.032 ~ 0.077	-		
		Clearance between drive gear shaft and cover hole	0.040 ~ 0.094	-	Replace bush or cover	
		Diameter of gear shaft	∅16.950 ~ ∅16.968	∅	Replace gear shaft	∅17e7
		Diameter of driving gear bush	∅28.000 ~ ∅28.033	∅	Replace bush	∅28e7
		Backlash: Between crank gear & idle gear	0.15 ~ 0.25	0.8	Adjust back-lash	
		Backlash: Between oil pump drive gear & idle gear	0.15 ~ 0.25	0.8		
	Valve opening pressure	Oil pressure control valve (kg/cm²)	4.0 + 0.8	0.8	Replace valve	
		By-pass valve for filter element (kg/cm²)	1.8 ~ 2.3	0.8		
		By-pass valve for full oil filter (kg/cm²)	-			
		Relief valve for oil pump (kg/cm²)	10 ± 1.5		Replace valve	
		Spray nozzle control valve (kg/cm²)	1.5 ~ 2.0			
	Oil filter	Damage of oil filter cartridge			Clean or replace	

Group	Part	Inspection Item	Stand value for assembly	Limit for use	Correction	Remark
Cooling system	Heat Exchanger	Heat exchanger & water pump for corrosion, damage & improper connecting			Correct or replace	
		Test for leakage (air pressure) (kg/cm²)	3.0		Submerge in water and replace if air bubbles found	
		Pressure valve for opening pressure (kg/cm²)	0.9			
	Water pump	Delivery volume l/min - Engine speed 2,300rpm - Water temp.85 ˚C - Back pressure : 0.5 kg/cm²	260 Lit/min		Check the water passage	For any restrictions
		Clearance between impeller & housing	0.35		Replace if impeller & housing are intact	
		Perpendicularity of pulley	0.3		Adjust by a bench press	
		Fan belt depression (with thumb)	10 ~ 15	15	Adjust	
	Cooling water temp	Operating temperature (permissible temp) ˚C	85	95	Must not exceed this valve	
		Permissible temperature in a short time. ˚C	103	-		
	Thermostat	Thermostat opening temp. ˚C (under atmospheric pressure)	71		Replace	
		Full opening temp. ˚C	85		Replace if defective stroke min. 8mm	
Fuel system	Piping & others	Fuel pipe, injection pipe & nozzle holder for damage, cracks, improper packing, etc.			Repair or replace	
		Fuel filter cartridge for damage or dimple			Replace cartridge	
	Injection pressure of injection nozzle (kg/cm²)		220		Adjust by shim	1st :160 , 2nd : 220
	Operating pressure of overflow valve (kg/cm²)		1.0 ~ 1.5		Replace valve	
	Projection height of nozzle from the cyl. head surface(mm)		3.6 ~ 4.1		Replace cyl. head & nozzle	
Inspection at completion	Running-in the engine				Refer to supplement “running-in”	
	Cylinder pressure	Compression pressure of cylinder (kg/cm²)	24 ~ 28	24 or more	Correct	at 200rpm or more more(20 ˚C)
		Compression pressure difference of each cylinder	±10% or less against average		Correct	